JANUARY 1960

Power Engineering

Special Issue

Changing Shapes in the World of Power Engineering

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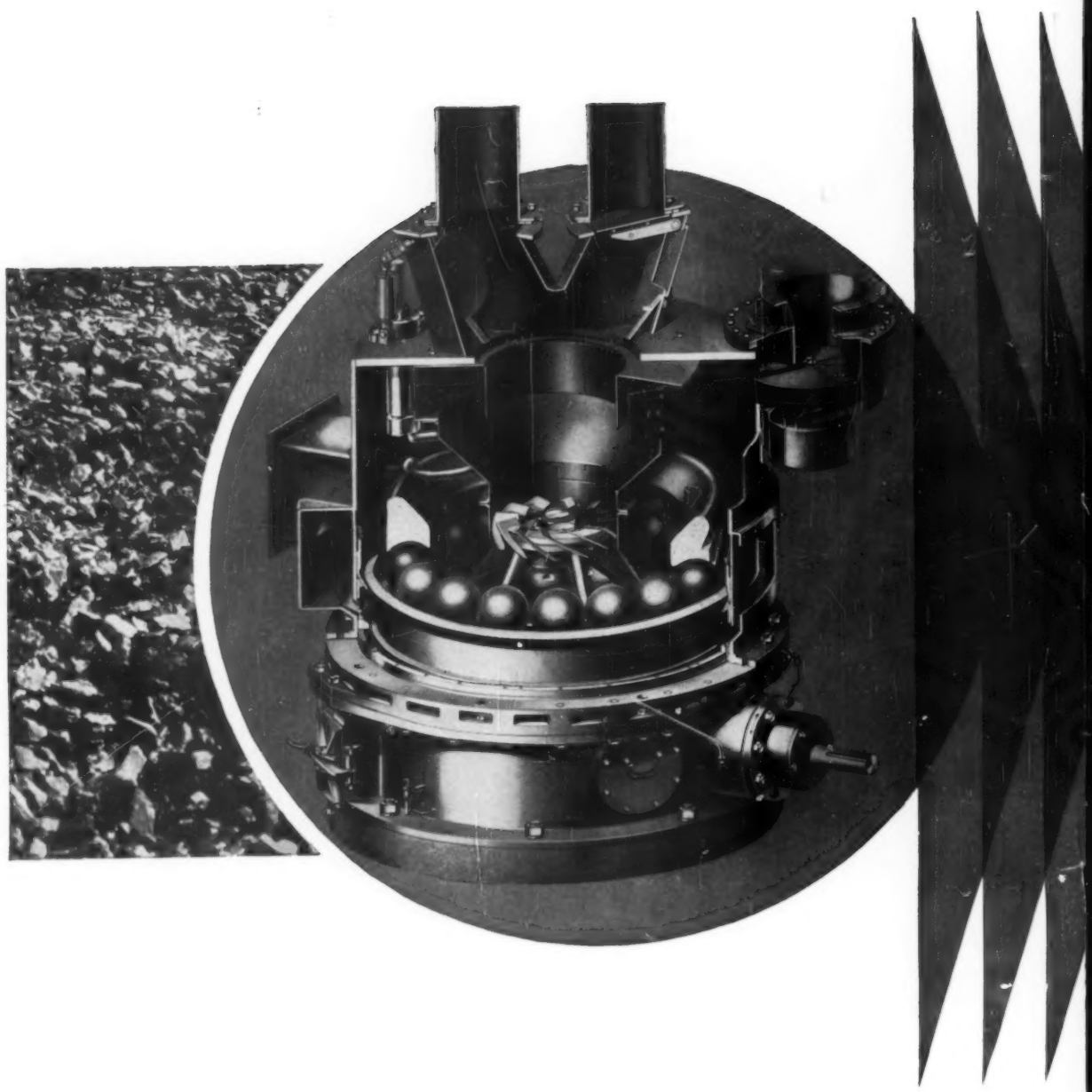

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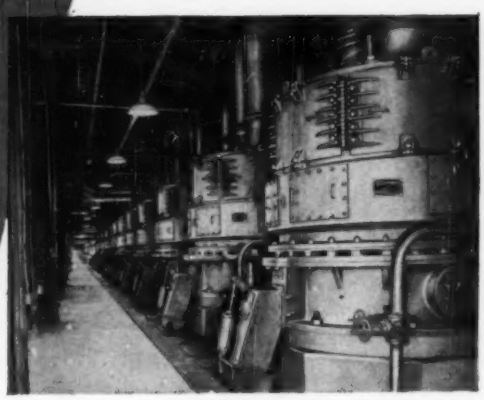

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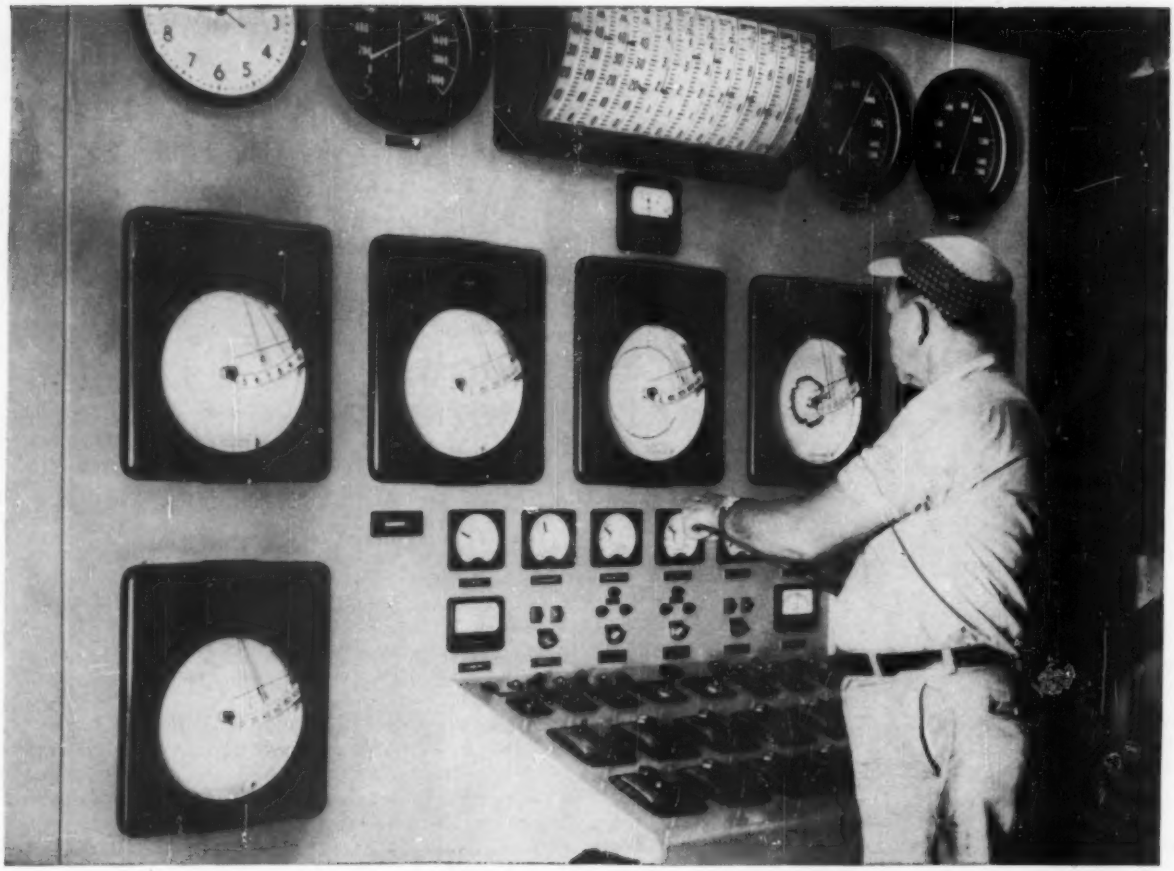

Control Room for Cyclone Furnace Boiler at Mathews No. 2 Power Plant of Greenwood Mills, Greenwood, S. C. Bailey MINI-LINE System concentrates controls at operator's station.

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PUBLISHED SINCE 1896 FOR POWER ENGINEERS IN PRIVATE AND PUBLIC UTILITIES AND INDUSTRIAL ARTS

ENGINEERS' PREVIEW

LOOKING AHEAD at the recent National Power Conference of ASME and AIEE, Glenn Warren of ASME touched on many problems facing the power industry, including an installed capacity of 600,000,000 kw by 1979, and a market representing 5 to 6 per cent of our gross national product. This is about three times present figures. Warren predicts that only about 10 per cent of this, or 60,000,000 kw, will be atomic power, and he ventures a guess that "fossil-fuel power is far from its peak development."

This 3 to 1 expansion of capacity in two decades will create problems. Warren sees relatively little increase from present maximum temperatures and pressures, because of the relatively small gain and the extremely high cost. He foresees no insurmountable obstacles except system conditions to units of a million kw, and expects a resurgence of the 1800-rpm low-pressure units as a means of reducing losses. He also predicts a big future for the gas turbine, and pointed out its broader implications and possibilities of improving cycle efficiency of a steam plant, either by exhausting the turbine to the boiler furnace, or using a high-pressurized furnace as a combustion chamber of the gas turbine, possibly some six or eight atmospheres. Either offers approximately 15 per cent increase in output and 45 per cent increase in efficiency, Warren stated.

JULIAN NARDI, 62, chief mechanical engineer of Ford, Bacon & Davis, New York engineering and management consultants, was among the 26 persons who died in a Piedmont Airlines plane crash October 30 in Virginia. Born in Chicago, Mr. Nardi attended Randolph-Macon Academy, Bedford, Va, and received his mechanical engineering degree from the University of Illinois in 1921. He began his career as a draftsman with Sargent & Lundy, Chicago, and in 1922 moved to Stone & Webster, Boston, where he rose from draftsman to senior mechanical engineer. He joined Ford, Bacon & Davis in 1935, and became chief mechanical engineer of the firm in 1950.

NATIONAL ELECTRIC WEEK will be February 7-13. Theme is Electricity Sparks the '60s. The Week is endorsed by 15 associations, through the National Electric Week Committee, 290 Madison Ave, New York 17, N. Y. Today, 80 years after Thomas Edison's first practical electric lamp, in the U. S. alone, two million people work in the electrical industry, and one-and-a-half million more work in electronics.

AMERICAN RED CROSS has announced official adoption of the mouth-to-mouth technique of artificial respiration for adults as well as children. The technique was declared the most practical in a unanimous verdict of a committee of the National Academy of Sciences-National Research Council after a thorough review of artificial respiration data.

INDUSTRY BRIEFS: Rockwell Manufacturing Co will build a new 150,000-sq-ft addition to its plant at Pinneberg, West Germany, for the manufacture of liquid meters, valves and woodworking power tools for the European and world markets.

Crane Packing Co of Morton Grove, Ill., has completed the first plant devoted exclusively to the full scale processing of Du Pont Teflon — a postwar plastic material that has done much to further major advancements in rocket and missile, aviation, electronic and chemical industries.

Babcock & Wilcox Co reports the receipt of a contract for more than $8,000,000 to manufacture a Universal Pressure once-through steam generator for the Public Service Electric and Gas Company's Sewaren Generating Station, Woodbridge Township, N. J.

Thomas Alva Edison Research Laboratory at West Orange, N. J.,

has been designated the central research laboratory for all McGraw-Edison Co operations.

An Award of Honor, the National Safety Council's highest form of recognition, has been presented to the Chrysler Corporation-operated Michigan Ordnance Missile Plant for working more than 3,000,000 manhours without a disabling injury.

Consolidated Edison Co will spend $5,000,000 for the control of air pollution in the three power plants it has recently purchased from New York City. Program will involve building high-pressure boilers with complete equipment for the control of air pollution, the abandonment of some obsolescent coal-fired low-pressure boilers, and the conversion of others to oil.

UNIQUE experiment in attacking problems of documenting the world's fast-growing technical literature was a conference of more than 200 people from 10 countries, held recently in Cleveland. Called the International Conference for Standards on a Common Language for Machine Searching and Translating, the meeting was sponsored by Western Reserve University and the Rand Development Corp.

WRU, with its Center for Documentation and Communication Research, has been a pioneer in machine documentation of technical information. News at the conference was that General Electric will build a high-speed prototype of WRU's searching selector. This new machine, known as the GE-250, will be able, for instance, to search the entire 1037 pages of Gone With the Wind in 3½ minutes, picking out the number of times a word or a combination of words appeared. The GE-250 will be the basis for the American Society of Metals' new metallurgical searching service, which will have a 100,000-titles-per-hour capacity. This new facility will be known as the ASM Metals Documentation Service.

The conference has arranged for the perpetuation of its work through a 10-country committee headed by Dr. Brian Vickery of the Imperial Chemicals Industries of Great Britain. General secretary is Allen Kent of WRU's Center for Documentation and Communication Research. Work will go forward in four areas: research, nomenclature, exchange of materials and information, and exchange of personnel.

J. HARRIS WARD has been elected president of Commonwealth Edison Co, succeeding John W. Evers, who has retired. Ward is a native of Kansas City, Mo, and came to Edison in 1938 as an investment analyst. He was elected secretary of the company in 1948, vice-president in 1951, vice-president and treasurer in 1952 and executive vice-president in 1955. He has been a director since 1957.

William Parkerson has been named Supervisor of Statistics at the Edison Electric Institute. A graduate engineer of Tulane University, Parkerson started his utility career with Louisiana Electric Co (now Gulf States Utilities Co), Lake Charles, Louisiana. Subsequently he served with Public Service Co of Oklahoma, Central Power and Light Co, Middle West Service Co and Ebasco International Corp. He is a member of the American Statistical Association and of ASME.

Joseph L. Fisher, formerly secretary and associate director of Resources for the Future, has been elected president and executive director of the organization. He succeeds Horace M. Albright. Irving K. Fox, director of water resources studies, has been elected associate director.

Alfred C. Wenzel has been named market development manager of Republic Flow Meters Company, a subsidiary of Rockwell Manufacturing Co. Wenzel has been associated with Smoot Engineering Corp, later combined with Republic, and Republic for 32 years. He has been production management manager, chief contract engineer, and field service engineer, and is a mechanical engineering graduate of the Polytechnic Institute of Brooklyn (1927).

WILBUR G. HUDSON, 84, died October 22. He was the author of a series of fine articles for POWER ENGINEERING on all types of coal-handling equipment. He was born in New York, and graduated from Cornell University in 1897. During World War I he served as vice-president and chief engineer of Curtis Wright Airports Corp, and became chief engineer of the Link-Belt Co Chicago plant. After his retirement he was active as a consulting engineer specializing in the materials handling field.

FRANK J. TRELEASE, 72, pioneer builder of natural gas pipelines, died October 2 in Oxford, Md. He retired in 1947 as a senior consulting engineer with Ford, Bacon & Davis, Inc, after 33 years with the New York engineering firm. Mr. Trelease was in charge of construction of the Lake Pontchartrain Bridge in Louisiana and, at the beginning of World War II, of the Electric Boat Corporation's submarine plant in Groton, Conn.

15 ELECTRIC POWER COMPANIES in eight states are joining forces to conduct the largest electric load flow study ever undertaken. This will involve the operation of the interconnected systems of the Ohio Valley Electric Corp and its sponsoring companies. OVEC was formed by 15 private power companies to supply 2,000,000-kw load to the AEC plant at Portsmouth, Ohio. The IBM 709 computer at the Arlington (Va) Research Center of C-E-I-R, Inc, will be used to conduct the study, analyzing a system of 333 stations and 532 transmission lines. Some 10 hours on the computer will be required for the study, as compared with eight weeks required by a network analyzer at almost triple the cost.

MEETINGS: Instrument Society of America will hold three regional conferences in 1960 instead of one national meeting. First conference will be held in Houston, February 1-4; second in San Francisco, May 9-12; while an International Conference and Exhibit will be held in New York City, September 26-30, in conjunction with ISA's 15th annual members' meeting.

National Industrial Electric Heating Conference will be held February 1-4 at the Netherland Hilton Hotel in Cincinnati. This is the fourth such conference under the Industrial Electrification Council.

COOLING TOWER INSTITUTE has transferred its offices from Palo Alto, Cal, to Houston, Texas. Operation of the CTI programs will continue in the broad areas of research and in the publication of industry standards, under the direction of James L. Willa, CTI manager, with offices at 1120 West 43rd St, Houston 18.

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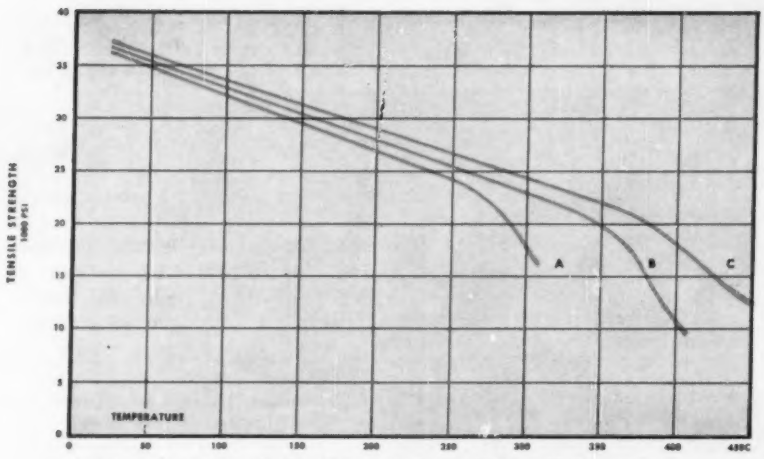

A. Silver content normal. **B.** Silver 8.7 ounces per ton. **C.** Silver 28 ounces per ton.

Silver-bearing coppers give a margin of safety in operating conductors at elevated temperatures

In heavily loaded motors and generators, the windings, collector rings, and commutators must retain their strength at the higher operating temperatures that have become the rule. And there are now many other places where copper conductors must operate at temperatures well above those heretofore considered normal.

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The curves are the result of tests made by the Metallurgical Research Laboratory of The American Brass Company.

There are three standard Anaconda alloys: Silver Bearing Copper-111, silver 8 troy ounces per ton, average conductivity, annealed, 101%; Silver Bearing Copper-112, silver 10-15 troy ounces per ton, average conductivity, annealed, 100.5%; Silver Bearing Copper-113, silver 25-30 troy ounces per ton, average conductivity, annealed, 100%.

More detailed information concerning the influence of silver on the tensile properties of high-conductivity copper at elevated temperatures is given in Publication C-25, "Anaconda Copper for Electrical Conductors." Included are curves for yield strength at 0.2% offset and 0.5% extension—indices of the limits of elastic behavior—of interest to design engineers.

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DLP COPPER-104 (Cu 99.9+, P 0.01) average conductivity, annealed, 97%. High-conductivity type of phosphorus deoxidized copper excellent for brazing, soldering—is being used increasingly by electronics manufacturers—also in such places as transformer bushings.

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RIGHT: 90-degree bends made in 3", 3½", and 4" Everdur raceways.

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WHAT THEY TELL US

▶ **COMBINATION** pressure relief valve and vacuum breaker, about which we queried in this department in November, drew this clarifying answer from C. Harold Berry, Gordon Mackay Professor Emeritus of Mechanical Engineering at Harvard University:

> Your November issue, page 6, in the lower right-hand corner, displays ignorance of a gadget that has been in my cellar at home for at least 27 years.
>
> Boston Brass Co, 137 Bacon St, Waltham, Mass., makes the B.B. 3-in-1 valve, which is a combined fusible plug, pressure relief (set for 100 psi or as desired) and vacuum breaker. It is intended for installation on the cold-water inlet to a hot-water range boiler, but I see no reason why it might not be applied to a heating system, perhaps with the fusible plug replaced by a brass plug.

▶ **TILTING-TYPE STEAM TRAPS,** about which W. F. Dralle inquired here recently, are still being made. Reader Robert A. Spence of South Lincoln, Mass., tells us that many of these traps are in use locally. The manufacturer is:

> Templeton Bros.
> 115 Business St.
> Hyde Park, Boston, Mass.

▶ **FAST BOILER TUBE** repair was described by James M. Curran in the Handbook section of POWER ENGINEERING for last October, page 108. Now reader E. S. Adam in Ontario writes:

> Please tell readers to be careful. We know of one man who almost lost his life from a similar quick repair. The steam built up in the tube stub caused backing up of water, with resulting overheating of metal and an explosion.

To this, James Curran replies:

> E. S. Adam's comment is very interesting. But if you lose the water in the boiler due to a perforated tube, what must be done, if no spare tubes are available and the plant must be kept operating?
>
> It has been three years since the remaining part of the damaged tube was filled, welded, and crimped over, and no trouble has occurred in all that time. Possibly the repairs mentioned by Mr. Adam were not efficient, if an explosion occurred. It is well-known procedure to cut the tube and fill the remaining part up with welding. I have never heard of a tube causing an explosion, if the work was properly done.
>
> Col. John Stevens built the first porcupine boiler that operated on the Hudson River. Of course, this type of boiler is obsolete now. It had 100 tubes, 18 in. long and 2 in. in diameter. Possibly this boiler was not safe, as the heat playing on the tubes caused overheating of the metal and forced the ends of the tubes out of the shell.

▶ **LOS ANGELES COUNTY'S** new Harbor General Hospital at Torrance will have a $1,660,000 central heating and refrigeration plant and laundry building designed by M. A. Nishkian & Co, consulting engineers. Describing this new installation, M. A. Nishkian explains:

> The heating plant will consist of two 22,000,000 Btu per hour forced-circulating, high-temperature-water generators with a nominal temperature of 400 F, with a minimum return temperature of 240 F. The HTW units will be designed and constructed for 300 psi in accordance with ASME Code, and designed to burn both natural gas and fuel oil.
>
> Refrigeration equipment will consist of two 600 ton and one 500 ton capacity absorption refrigeration machines, using lithium bromide as a refrigerant. These machines will be completely packaged including controls, solution, refrigerant and purge pumps, and will generate chilled water at 43 F with return water at 63 F, using 85-F condensing water. Energy to operate the units will be obtained from the high-temperature water generated by high-temperature hot water generators.
>
> Chilled water will be circulated throughout the system by means of electric motor-driven centrifugal pumps. Condensing water will be cooled by means of a three-cell, induced-draft cooling tower.
>
> HT water, steam, chilled water, cooling water, air, non-potable raw water, fuel gas, fuel oil and diesel oil piping will be standard weight black steel pipe, with standard butt weld fittings. Condensate piping will be extra strong black steel. All soft water piping will be type-K copper tubing.
>
> Our engineering evaluation indicated that this system would provide the most economical capital cost, and the most economical operating costs for the production of both the chilled water and high-temperature hot water.
>
> This, combined with the fact that the laundry load will be of considerable magnitude, meant that the combining of the laundry structure with the HTW and refrigeration plant worked out to be the most feasible and economical for a plant of this type.

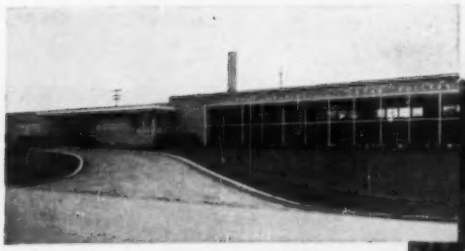
▶ **ALTHOUGH NOT AN EXPERT** on turbines, reader W. Cronin of Dublin, Eire, has definite views on the emergency turbine repair job described in last September's issue (on how Westinghouse repaired a Memphis turbine in 34 days). Cronin writes:

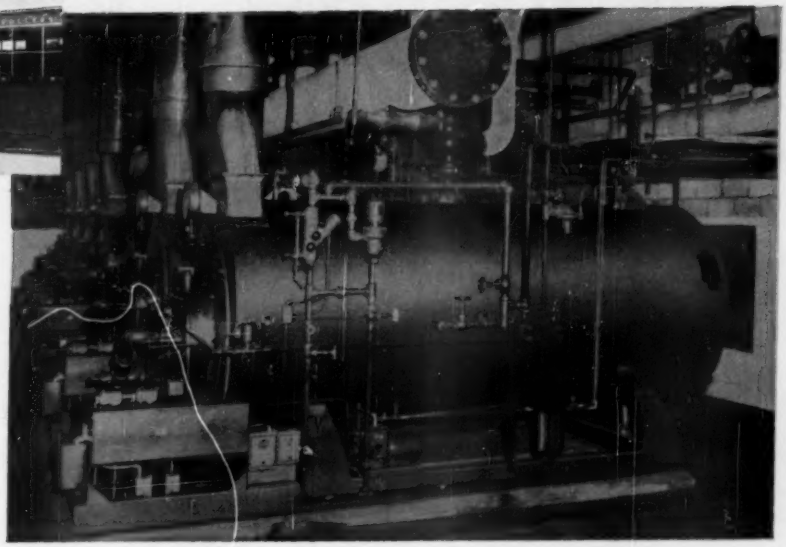
> . . . while I do not understand why your country buys foreign turbines, I would like to comment on the remark made in the article as to what would happen if the turbine had been purchased from a foreign manufacturer.
>
> My view is that if it had been purchased from a continental firm, such an accident would not occur as they would not use such an out-of-date design. Most continental firms make the shroud integral with the blade, and each section is welded in a special manner and no riveting is required.
>
> I would be interested to know what type of steel was used to make the shroud. Sometimes the failure is due to the material cracking near the rivet holes, if an austenitic steel is used. Another point is that it is not the practice here to weld the lashing wire to each blade, in order to leave them more flexible, and the best of welding may change the metal structure.

▶ **GROUND-BREAKING** for the 18-story United Engineering Center at United Nations Plaza in New York City featured Herbert Hoover as spokesman. In remarks just before he turned the first shovel-full of earth at the site of the new Center, Hoover called the occasion . . .

> . . . an event of national importance. The engineering societies in our country comprise a great army of over 250,000 creative minds covering almost every branch of the profession . . . they are the foundation of security in our defense and the increase of the standards of living and comfort for our people . . . The engineer brings jobs and better homes. This is the high privilege of our profession. The purpose of this great building is to facilitate these goals. It will play a great part in American life. It will serve all mankind.

Never more steam than you can use . . .
never less steam than you should have!





One of the largest producers of graders, roadscrapers and rolling equipment, Galion Iron Works & Manufacturing Co., has six 125 HP Cyclotherms now operating, plans to add a seventh and eighth as steam demands increase. Automatic operation has been the big factor in helping Cyclotherm make the grade with the graders!

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With Cyclotherm Steam and Hot Water Generators, you buy steam capacity as you use it. No investment in excess capacity. No steam shortage with an outgrown boiler.

Cyclotherms give flexible capacity. You can add 518 lbs. of steam per hr. with a 15 HP Cyclotherm, or 25,875 lbs. per hr. with a 750 HP Cyclotherm. And there are 16 intermediate sizes to choose from.

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Yarway Bulletin WG-1814 describes the Color-Port Gage. Write for it.

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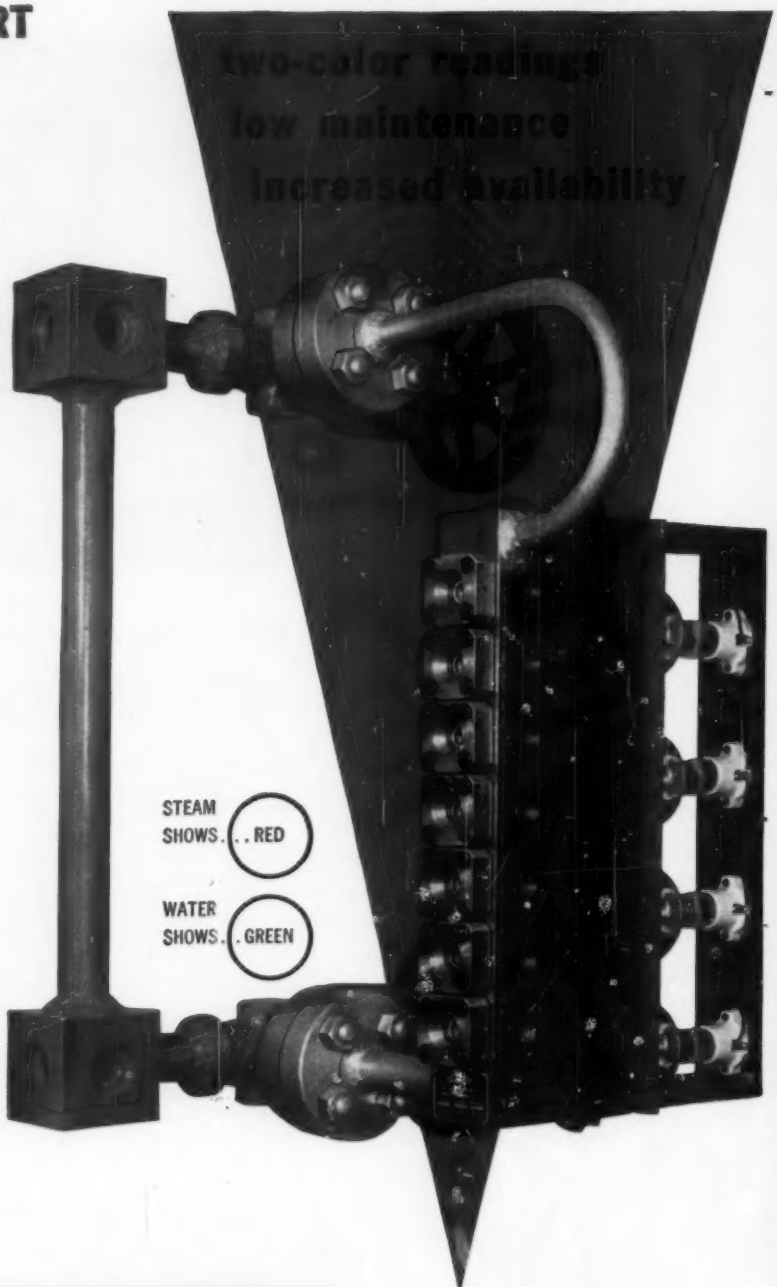

YARWAY COLOR-PORT . . . *a good way to specify high pressure water gages.*

boiler water level indication ?

YARWAY REMOTE LIQUID LEVEL INDICATORS

Boiler water levels and other liquid levels requiring remote indication can be handled completely by a Yarway system.

Heart of the system is the Yarway Remote Liquid Level Indicator that gives instant, accurate readings because the mechanism is operated by the boiler water or other liquid itself. The pointer mechanism is never under pressure. Clear, "wide vision" face permits easy readings from any angle

The Yarway Indicator conforms with A.S.M.E. Boiler Code Committee ruling (Case #1155) permitting two independent remote level indicators of compensated manometric type to replace one of two required gage glasses for boiler pressures 900 psi and above.

Electronic Secondary Indicators can be added at any point in the plant. Remote Hi-Lo Alarm Signals (lights and/or horns) can be connected for additional safety.

Primary indicators fully compensated for every pressure change in boiler also available.

For permanent record of changing levels, the Yarway Hi-Lo-Graph Recorder can be furnished.

Over 13,000 Yarway Remote Indicators have already been installed For full details, write for Yarway Bulletin RI-1825.

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FULLY COMPENSATED INDICATORS

for completely accurate indication under every boiler operating condition

ELECTRONIC SECONDARY INDICATORS

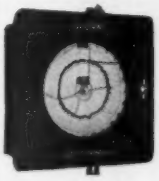
To supply additional indication at any point without pressure connections.

REMOTE SIGNALS

Hi Lo Alarms Lights and/or Horns.

RECORDERS

To provide permanent 24-hour record of liquid levels.



YARWAY

. . . a good way to specify remote liquid level indicators

Modern use of coal cuts fuel costs 22%

In addition, coal costs Uniontown Hospital $3.00 per ton less than gas!

Expansion of facilities at Uniontown Hospital, Uniontown, Pa., increased the demand for steam used for space heating, water heating, kitchen, laundry and sterilizing equipment. An engineering survey was conducted which indicated the need for a new plant rather than modernization of the old one. Hospital officials —working with Altman and Altman, Architects, and Paul S. Park, Consulting Engineer—decided to install a completely automatic steam plant. Coal continues to be used because it meets the hospital's rigid standards for cleanliness and has proved the most economical fuel. Not only has burning coal this modern way shown a 22% savings in fuel costs compared to the old plant but, per equivalent ton, coal actually costs $3.00 less than its nearest competitive fuel!

COAL IS LOWEST COST FUEL

Today, *when the annual cost of fuel often equals the original cost of the boilers,* you should know that bituminous coal is the lowest cost fuel in most industrial areas. And modern coal-burning equipment gives you 15% to 50% more steam per dollar, while automatic operation trims labor costs and eliminates smoke problems. What's more, tremendous coal reserves and mechanized mining procedures assure you a constantly plentiful supply of coal at stable prices.

CONSULT AN ENGINEERING FIRM

If you are remodeling or building new heating or power facilities, it will pay you to consult a qualified engineering firm. Such concerns—familiar with the latest in fuel costs and equipment—can effect great savings for you with the efficiency and economy of coal.

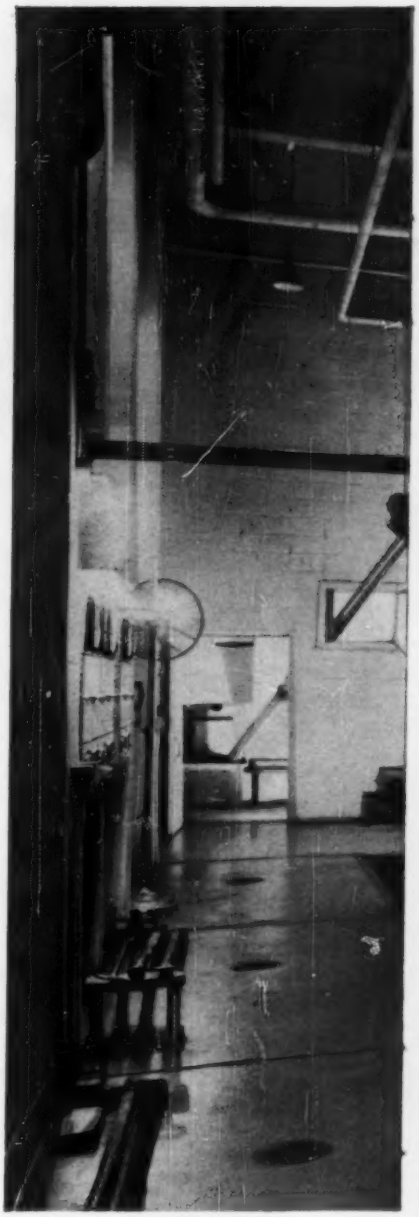
TECHNICAL ADVISORY SERVICE

To help you with fuel problems, the Bituminous Coal Institute offers a free technical advisory service. We welcome the opportunity to work with you, your consulting engineers and architects. If you are concerned with steam costs, write to address below or send coupon. Ask also for case histories booklet, complete with data sheets. You'll find them informative.

BITUMINOUS COAL INSTITUTE

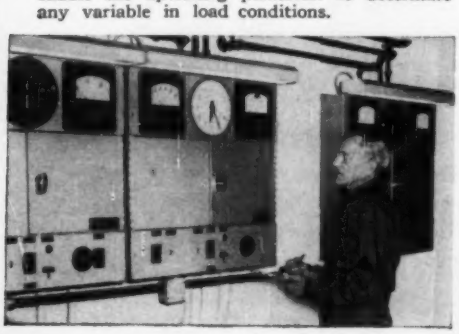
Department PE-01, Southern Building, Washington 5, D.C.

See our listing in Sweet's Files: A-30J/Bi; PE-4a/Bi; IC-18b/Bi



Coal is discharged into bin and gravity fed into hopper box, then moved by inclined screw conveyor into horizontal screw conveyor leading to stoker hoppers and boilers. Boilers are Keeler 10,000 lb/hr "CP" type units, 150 psi. Coal handling system by Auburn Foundry Company.

The completely enclosed electric-type combustion control panel (Cleveland Controls, Inc.) contains assembly units for all power control and coal handling operations. Steam flow meters, strategically located throughout the hospital, enable the operating personnel to determine any variable in load conditions.



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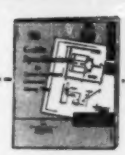
Guide Specifications, with complete equipment criteria and boiler room plans:



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Gentlemen: Please send me:

☐ GS-1 (low-pressure heating plant, screw-type underfeed stoker).
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☐ GS-3 (automatic package boiler for heating and process plants).
☐ Case histories on larger plants.

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Title _____

Company _____

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City _____ Zone _____ State _____

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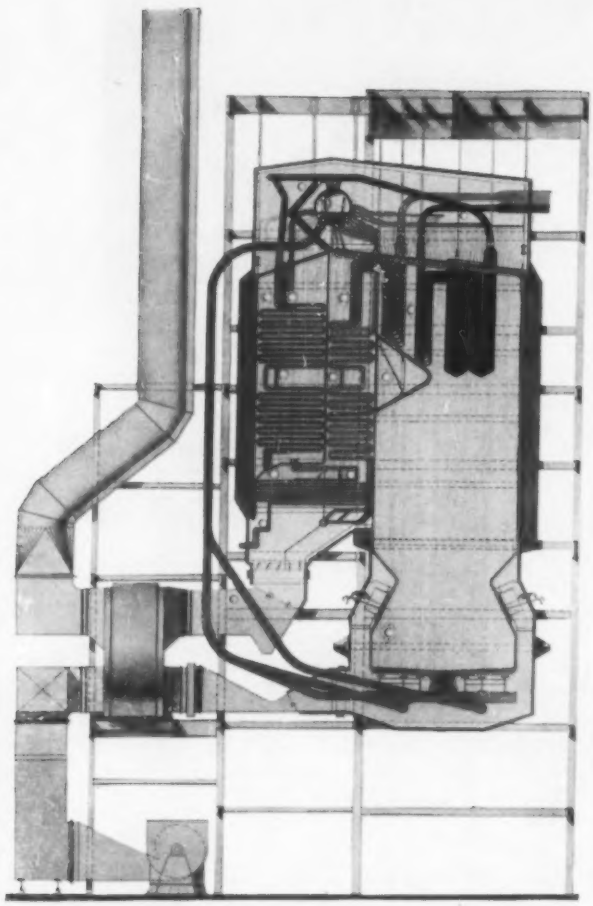
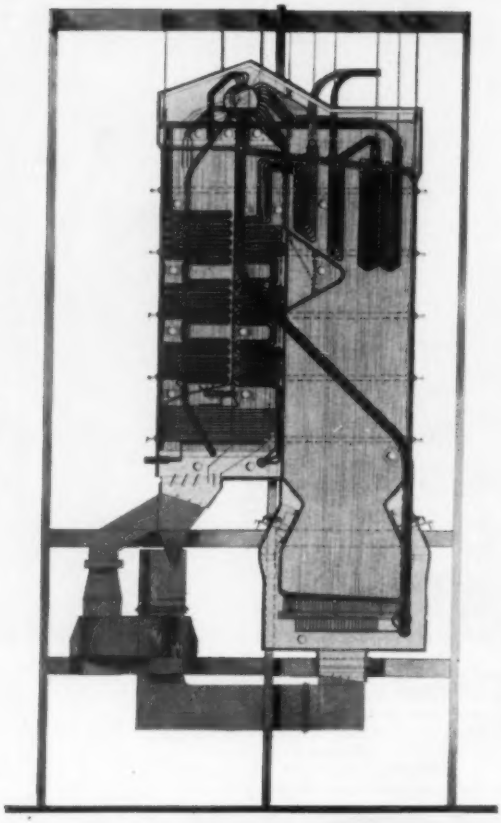
How The RILEY TURBO FURNACE



Texas Public Utility — 1,200,000 lbs/hr
1005/1005F; 2125 psig — Gas or Oil Fired

- Permits the use at any time of the most economical fuel available — a wide range of coals, lignite, fluid coke, natural gas, blast furnace gas, oil.
- Complete burn out of all combustible material virtually eliminates combustible loss.
- Nearly equal furnace performance with oil, gas or coal firing simplifies steam temperature control.



Florida Public Utility — 680,000 lbs/hr
1005/1005F; 1650 psig — Gas and Oil Fired

A FEW TURBO FURNACE CENTRAL STATION BOILERS INSTALLED AND UNDER CONSTRUCTION

*Delaware City Power Station
Delaware Power & Light Company
Delaware City, Delaware
Units No. 1, 2, 3

*Permian Basin Steam Electric Station
Texas Electric Service Company
Monahans, Texas

*Sterlington Steam Electric Station
Louisiana Power & Light Company
Sterlington, Louisiana

Rockwell Station, Unit No. 6
Manila Electric Company
Manila, Philippine Islands

*North Lake Steam Electric Station
Dallas Power & Light Company
Dallas, Texas
Two (2) Boilers

*Turner Unit No. 4
Florida Power Corporation
Enterprise, Florida

*Little Gypsy Steam Electric Station
Louisiana Power & Light Company
Little Gypsy, Louisiana

Agua Fria Station, Unit No. 3
Salt River Power District
Phoenix, Arizona

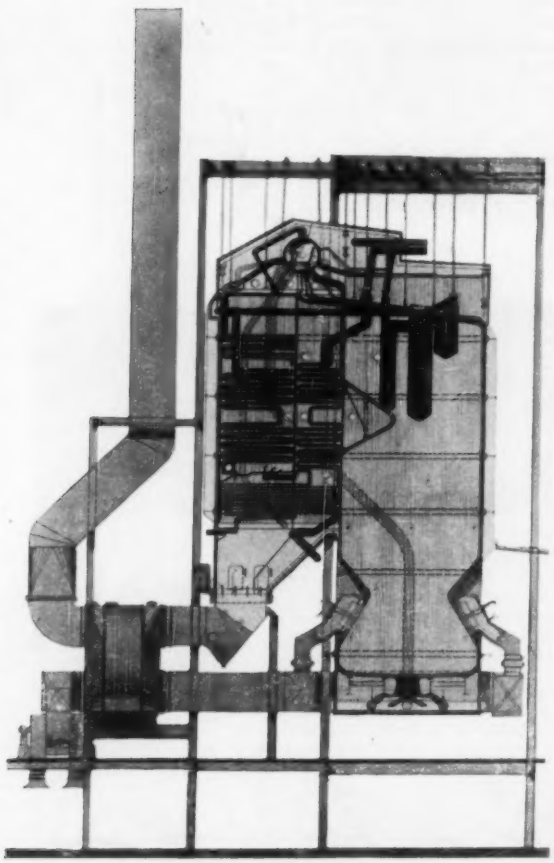
Michaud Steam Electric Station
Unit No. 2
New Orleans Public Service, Inc.
New Orleans, Louisiana

*Installed

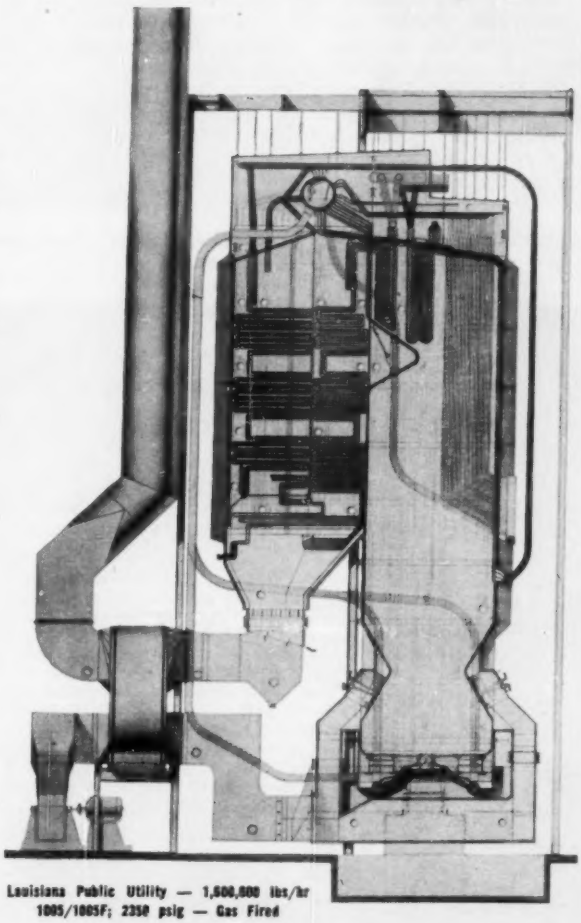
A survey of your plant by a qualified consulting engineer could show ways of making surprising savings in your power costs.

Helps To Lower The Cost Per KWH

- Flyash reinjected into furnace bottom eliminates cost of disposal, recovers combustibles. Quenched granulated slag is saleable.
- Prompt ignition and stable flame, even under adverse conditions, assure safe operation.
- Permissable higher furnace heat release rates result in smaller structures for given capacities.
- Almost entire absence of furnace wall deposits eliminates need for wall blowers, sustains high furnace efficiency, keeps uniform furnace performance.
- Opposed firing and uniform firing across the entire furnace width remove the limitations on furnace widths inherent in other firing methods.
- One level burner operation results in lower building costs and ease of operation.



Texas Public Utility — 825,000 lbs/hr
1005/1005F; 1750 psig — Gas and Oil Fired



Louisiana Public Utility — 1,600,000 lbs/hr
1005/1005F; 2350 psig — Gas Fired

RILEY STOKER CORPORATION WORCESTER, MASSACHUSETTS

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RILEY

STEAM GENERATING & FUEL BURNING EQUIPMENT

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See why ALCOA ALUMINUM makes a good design habit

Requirement: Low-cost, corrosion-resistant heat exchanger material

Key to Good Design: Specify Alcoa Aluminum Tube and Sheet

If corrosion resistance, long life, product purity and economy are considerations in your heat exchanger application, specify aluminum! ALCOA® Aluminum has been solving such problems for over 40 years.

In the petroleum industry, ALCOA Aluminum Tubes serve in main column overhead condensers where their freedom from fouling and excellent heat transfer properties have made them a natural selection. Heat exchangers made of ALCOA Aluminum Tube and Plate are used in the production of ammonia, nitric acid, vegetable oils, naval stores, naphthalene, hydrogen peroxide, oxygen and urea. These and other processes call for heat exchangers with combinations of high strength, excellent sub-zero physical qualities, high thermal conductivity, or nontoxic and noncatalytic properties. ALCOA Aluminum alloys meet all these requirements.

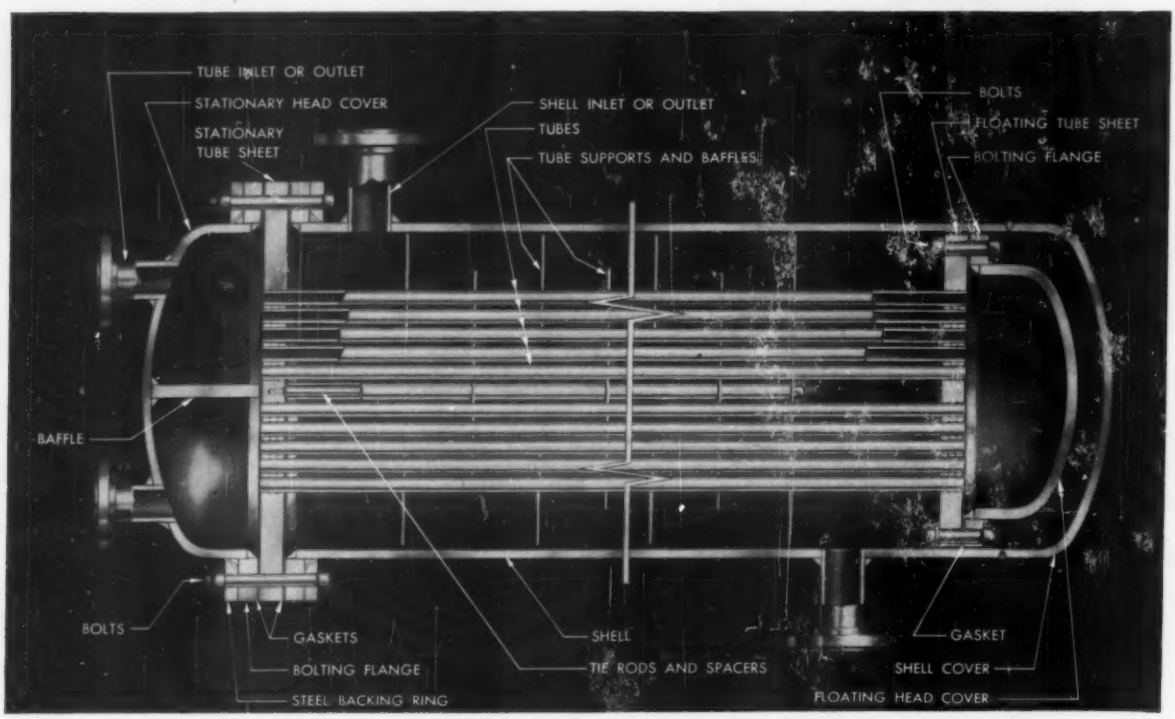
As for cost, ALCOA Aluminum Tube is the most inexpensive. In the common sizes it costs one-third less than mild steel, one-half as much as admiralty, and one-fifth that of stainless.

ALCOA Aluminum alloys are ideally suited to a wide range of maintenance methods. For relatively soft or loose scale, water jets and brushes are usually satisfactory. Wet sandblasting as well as chemical cleaners may be used effectively.

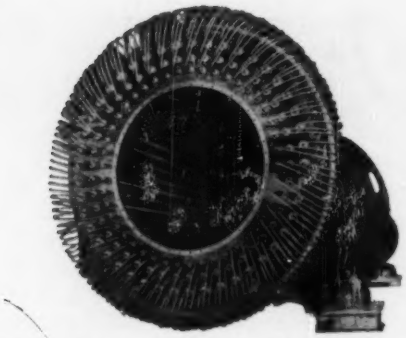
ALCOA engineers have worked closely with all segments of the process industries for over 40 years, and can help you specify the aluminum alloy best suited to your heat exchanger and other process applications. ALCOA's unparalleled experience in this field is available to you for the asking. Write to the address below, stating your requirements as specifically as possible. ALCOA's development engineers will welcome the opportunity to work with you on your problems.

You can also take advantage of the wide selection of free ALCOA literature on aluminum for heat exchangers and other process applications. Simply check the booklets you want on the coupon and mail to the address below. ALCOA will forward your material promptly and without obligation.

ALCOA is conducting a series of engineering conferences on process industries applications of aluminum during 1959 in a number of major cities. Contact your nearest ALCOA sales office for full particulars and dates.



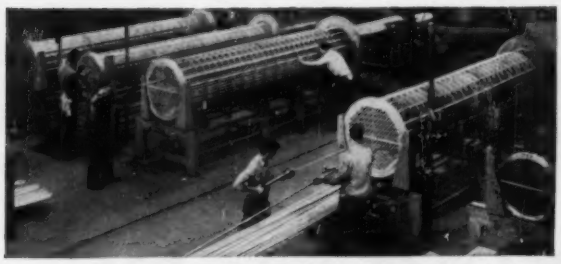
For certain processes where corrosive or sensitive materials are involved, it is often advisable to use aluminum for entire heat exchanger systems to avoid system corrosion and contamination of the product. A typical all-aluminum heat exchanger is shown here. Alloy recommendations are given in the table opposite.



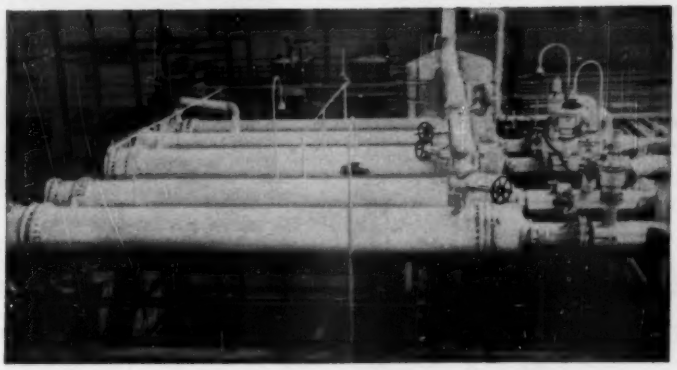
Alcoa Aluminum Tubing protects color in the world's largest rotary steam-tube drier. The drier measures 10 ft in diameter by 100 ft long.

A Midwest utility saved 50 per cent on tubing costs by using Alcoa Aluminum instead of admiralty for tubing in this surface condenser. Successful operation of this unit has led to the installation of similar units by other utilities. This use demonstrates aluminum's economy and superior resistance to ammonia, carbon dioxide and hydrogen sulfide.

A battery of all-aluminum heat exchangers in a polyethylene plant. Selected for initial low cost, these aluminum exchangers provide freedom from product contamination as well as desirable low temperature properties.



Construction of a heat exchanger utilizing Alcoa Aluminum Tube. Superior working properties plus the cold-drawing method by which Alcoa seamless heat exchanger tubes are produced results in close dimensional tolerances and smooth inside and outside surfaces.



This all-aluminum dephlegmator in a large coke plant is used for the regeneration of ammonia liquor in a hydrogen sulfide scrubbing operation. Aluminum tubes lasted five times longer than steel tubes in a similar use.

Alloy Recommendations for Aluminum Heat Exchanger Construction

	Alcoa Designation	ASTM Specification*	Alloy
Tubes	3003-H14	B234	M1A
	Alclad (inside) 3003-H14	B234	clad M1A
	Alclad (outside) 3003-H14		clad M1A
	Alclad (both sides) 3003-H14		clad M1A
	6061-T6	B234	GS11A
	6062-T6	B234	GS11C
Tube Sheets	3004-H112	B178	MG11A
	Alclad 3004-H112	B178	clad MG11A
	6061-T6	B178	GS11A
	Alclad 6061-T6	B178	clad GS11A
Baffles	3003-H14	B178	M1A
	Alclad 3003-H14	B178	clad M1A
Tie Rods	6061-T6	B273	GS11A
Shells & Headers	3003-H112	B178	M1A
	Alclad 3003-H112	B178	clad M1A
	3004-H112	B178	MG11A
	5052-H112	B178	GR20A
	5154-H112	B178	GR40A
Fittings	3003-F	B274	M1A as applicable
	6061-T6	B274	GS11A as applicable
Flanges	6061-T6	B247	GS11A as applicable

*Only the basic number is shown since Alcoa products are manufactured to the latest issue of the specification. The complete number would indicate the year of issue.

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Please send me the following literature covering Alcoa Aluminum in heat exchanger and other applications in the process industries.

- ☐ 10186 Alcoa Aluminum Heat Exchanger Tubes
- ☐ 20437 Aluminum Alloy Heat Exchangers in the Process Industries
- ☐ 10460 Process Industries Applications of Alcoa Aluminum
- ☐ 20849 Resistance of Aluminum Alloys to Weathering and Resistance of Aluminum Alloys to Chemically Contaminated Atmospheres
- ☐ 20272 Aluminum Alloys for Handling High Purity Water
- ☐ 20268 Resistance of Aluminum Alloys to Fresh Waters
- ☐ 20935 Designing to Prevent Corrosion

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HELPFUL WATER CONDITIONING DATA FROM BETZ

NEWEST APPROACH TO STEAM

■ The determination of the sodium content of steam has unveiled the causes of turbine and superheater deposits that heretofore have gone undetected.

Introduction

ENGINEERS concerned with the generation of steam are well aware of the problems produced by impurities in steam. With the trend toward higher steam pressures and temperatures in power plants, the need for increasingly purer steam has become more and more necessary. Designs of steam purifying equipment and drum internals have improved progressively. Yet steam with solids contamination of 0.5 ppm or less still causes troublesome turbine deposits.

Steam Testing Methods

Steam purity testing techniques also have undergone an evolution through the years to keep pace with the demand for purer steam. Originally, gross carryover could be detected by a simple check of pH or by a titration of the alkalinity or chloride content of the condensed steam. Where it was necessary to check with greater accuracy, the time consuming and cumbersome gravimetric determination of solids was employed.

Later, specific conductance was introduced for a rapid check of steam purity. This method is based on the fact that salts dissolved in condensed steam increase conductance. It was recognized early that carbon dioxide and ammonia dissolved in condensed steam contribute also to the conductivity. Therefore, it became necessary to calculate correction factors for the presence of these dissolved gases. Many mechanical degassing devices were designed and developed for the removal of dissolved gases and more recently acid regenerated cation exchangers have been employed.

The evolution of the specific conductance method has permitted rapid determination of steam purity and is the method most commonly employed today.

Yet many plants with steam purity of one micromho equivalent to 0.5 ppm of dissolved solids or less, continue to be troubled with superheater tube failures and turbine blade deposits.

It has become evident that the use of specific conductance for determining steam purity in the range of one micromho or less is not sufficiently sensitive.

Development of Sodium Method

Further improvements in steam purifying devices, the influence of boiler design and operating conditions on steam contamination, and the effect of anti-foams in bringing about the solution of these remaining problems, were at an impasse because of the lack of a sensitive testing method. Faced with this situation, many concerned with steam purity problems, have investigated more sensitive methods.

These investigations have led to the development of the sodium technique by flame spectrophotometry. The use of this method allows the detection of as little as 0.0004 ppm of sodium in dilute solutions under ideal conditions; equivalent to a dissolved solids content of 0.0012 ppm.

The initial applications of this method to steam purity studies under plant conditions were based on taking a series of "spot" samples under carefully controlled conditions to avoid contamination during the sampling period. Many studies were conducted using this procedure and a comprehensive discussion of these studies is presented in Betz Technical Paper No. 134B (copy on request).

Portable Field Equipment

Having demonstrated the sensitivity of the sodium technique, further study was given to adaptation of the equipment to permit continuous recording of the sodium content of condensed steam under plant conditions. Figure 1 shows the

Figure 1—Continuous recording sodium equipment in plant use.

PURITY MEASUREMENT

continuous recording sodium equipment in actual plant use. The supply of a sodium free air to the combustion chamber of the flame photometer was the major problem to be overcome. Air pollution in a boiler room is ever-present. This contamination can be especially troublesome in pulverized fuel plants. However, an MSA ultra air space filter which removes more than 99.9% of all dust particles of 0.3 microns in diameter or greater proved to be the answer. Outside air is passed through the filter and admitted to the burner at a slight positive pressure. This installation has been found completely satisfactory.

In the field equipment as pictured, the steam to be sampled is condensed in a cooling coil and the condensed sample is fed to the combustion chamber. A small portion of the sample is aspirated through a special hydrogen-oxygen burner. Any sodium in the steam will color the normally blue flame a bright yellow. The intensity of this yellow light is measured by the spectrometer at a wave length of 589 millimicrons, the wave length of sodium light. The amount of sodium in the steam is recorded on a strip chart of a Varian Recorder which is calibrated in parts per million as sodium using known standards. Normal procedure in plant studies has been to calibrate in the range of 0.0 to 0.2 ppm. For field work, the Model B Beckman Flame Photometer is used. This unit permits determining the sodium content of the steam with an accuracy of 0.002 ppm, equivalent to a dissolved solids content on the order of 0.006 ppm.

Plant Studies

A sufficient number of studies has been conducted using this portable equipment to attest to its accuracy and reliability for plant studies.

Figure 2 is a reproduction of a section of the strip chart recording the sodium content of the steam from a boiler operating at 650 psi. Previous studies had indicated that steam of acceptable purity on the order of 0.1 ppm of solids was produced at normal boiler rating of 100,000 pounds per hour. However, when the boiler load exceeded this rating, steam purity deteriorated rapidly. It had further been established that only by bringing the boiler back to ratings of less than 100,000 pounds per hour could acceptable steam purity be regained. In an effort to correct this condition new mechanical steam purifying devices were installed.

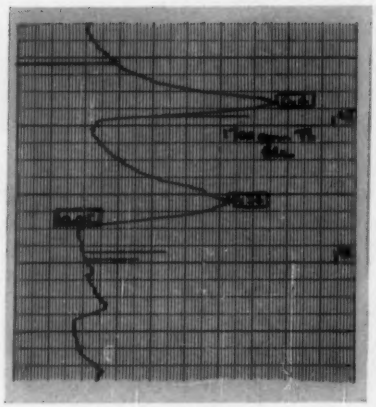

Figure 2.

The section of chart shown in Figure 2 records the sodium values following the installation of the new purifier. The peaks represent maximum steam impurity caused by load swings above 100,000 pounds per hour. These were only momentary increases and steam purity rapidly returned to normal even though boiler rating was maintained above rated capacity, clearly demonstrating the benefit of the new steam purifier. The "boxed" figures on the chart are the steam purity values as ppm of solids.

Figure 3 is an additional section of the chart following the application of an anti-foam to the boiler. It will be noted that the peaks have been decreased further by the application of the anti-foam.

Of significance is that steam purity was consistently below the range in which conductivity would have proved reliable. In the absence of the sodium technique the solution to this and similar problems would be difficult. The use of the sodium technique by no means will replace conductivity as a method of determining steam purity although the need for its greater accuracy has become more and more evident.

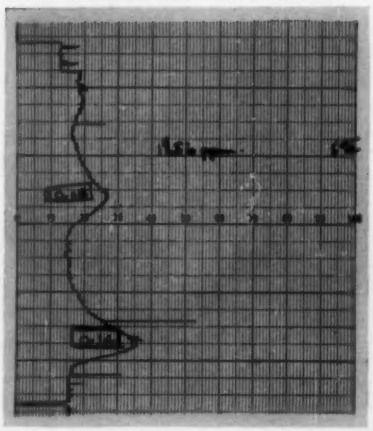

Figure 3.

Betz has pioneered the use of the sodium technique as well as the conductivity method in the study and solution of carryover problems. With an extensive background of experience in this field, we are ready to help in solving *your* particular carryover problem—effectively and economically. A Betz Field Engineer will be happy to call on you, without obligation. A good time to call him in is *today !*

BETZ LABORATORIES, INC.
Gillingham & Worth Streets, Philadelphia 24, Pa.

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MOTORS
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for your auxiliary drives...

Steam or Electric
Large or Small
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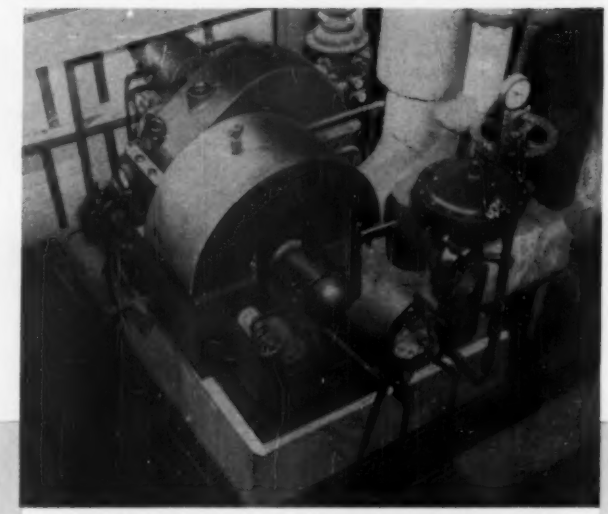
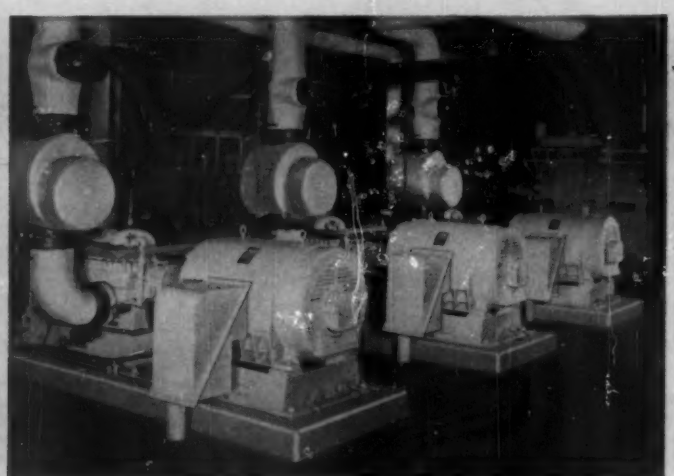


This Elliott geared turbine drives the induced-draft fan serving the 120,000-lb-per-hr boiler for a northeastern pulp mill. Elliott turbines are noted for simplicity, flexibility and year-in and year-out dependability.

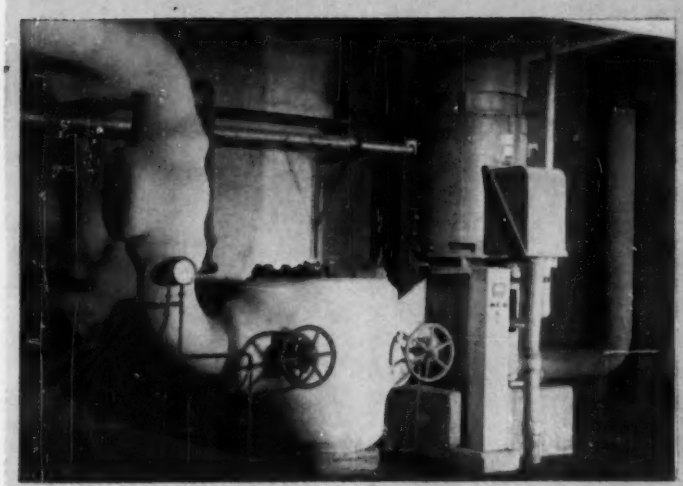
ELLIOTT Company
JEANNETTE, PENNSYLVANIA

Biggest boiler-feed pump motors in the country—each rated 5000 hp at 3600 rpm. Quick-access openings visible on near end of motor; removable swing-down filter panels on each side. Elliott "Super-Quiet" enclosures. 6000-hp Elliott motors will soon be operating.

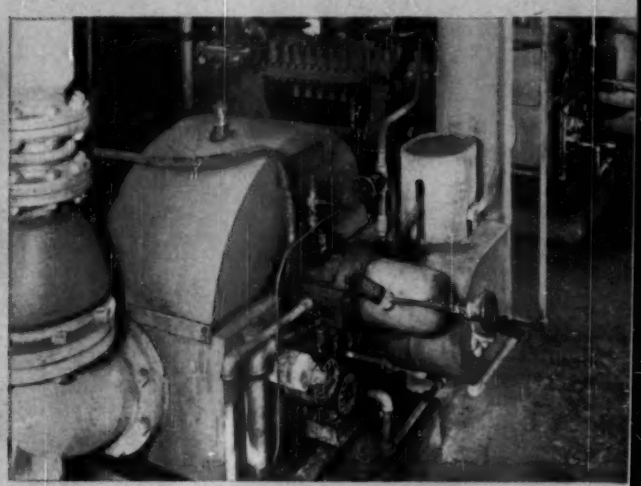


Heater drain pumps are driven by identical 200-hp, 3600-rpm Elliott motors. Elliott water strainers are mounted in pump inlets. Other Elliott products for power plants include condensers, ejectors, deaerating heaters, tube cleaners and expanders.

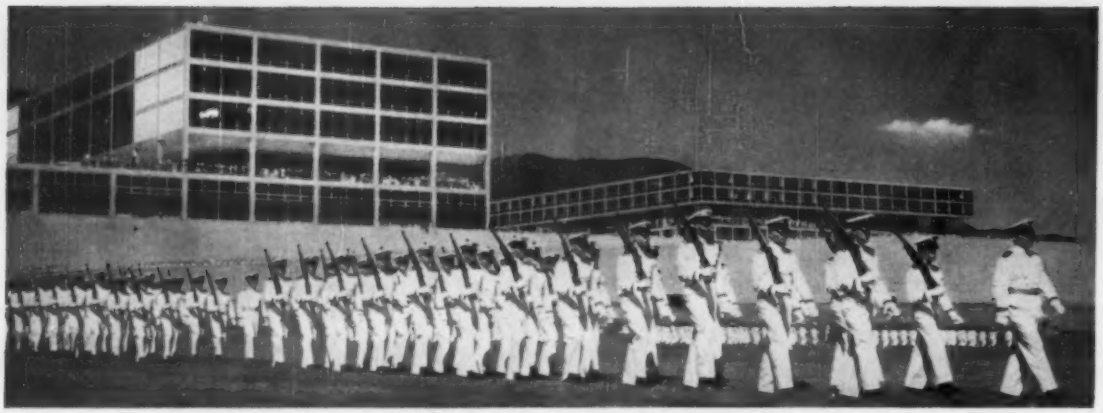
Dripproof 600-hp, 900-rpm Elliott motors driving line of coal pulverizers. Elliott FABRI-STEEL construction assures structural rigidity; FABRI-SEAL insulation assures maximum service life.



Here an Elliott 250-hp vertical, dripproof motor is shown driving a condensate pump. An Elliott twin basket water strainer which protects the pump can be seen at the left. Elliott C-W motor experience dates from 1888.

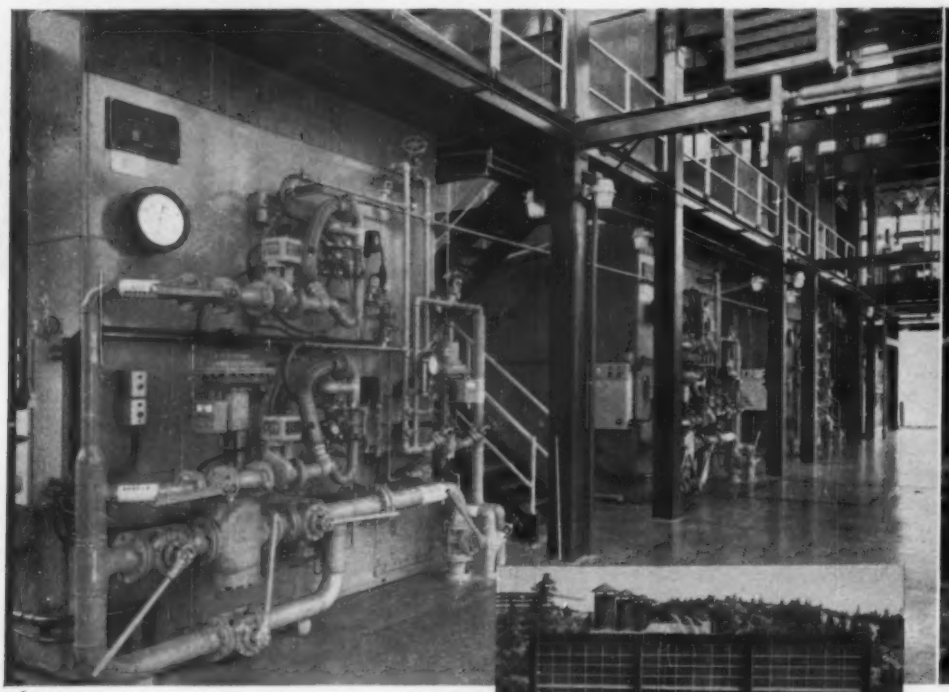


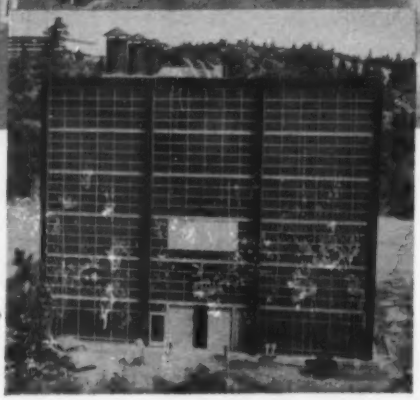
250-hp, 3550-rpm Elliott turbines drive boiler feeders in this industrial plant. All major auxiliaries in this station are Elliott turbine-driven. For over a half century, Elliott has been building turbines and turbine-generators.



Without breaking step, students march down ramp leading from academic and cadet living area onto the parade ground.

HIGH TEMPERATURE WATER HEATS





Compact and efficient, these three C-E LaMont Controlled Circulation Hot Water Boilers serve in the Academy's Academic Area plant. Each has a rated output of 100 million BTUs per hour.

The Academic Area plant, at right, houses the three C-E LaMont Controlled Circulation Hot Water Boilers shown above. The Service Area plant has two smaller C-E LaMont Boilers, each with a rated output of 30 million BTUs per hour.

Catalog HCC-2, describing the C-E Hot Water Boiler, available on request.

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS;

Nestled picturesquely in the Rampart Range of the Rockies, seven miles north of Colorado Springs, the new U. S. Air Force Academy is a fitting symbol of the prowess and prestige earned by this branch of our military.

Situated on a sloping site, the Academy grounds are graded, split-level fashion, into a number of broad terraces. Elevations range between 6,400 and 7,000 feet above sea level. The school is divided into two general areas — one for service buildings and one encompassing academic, physical education, dormitory and hospital facilities.

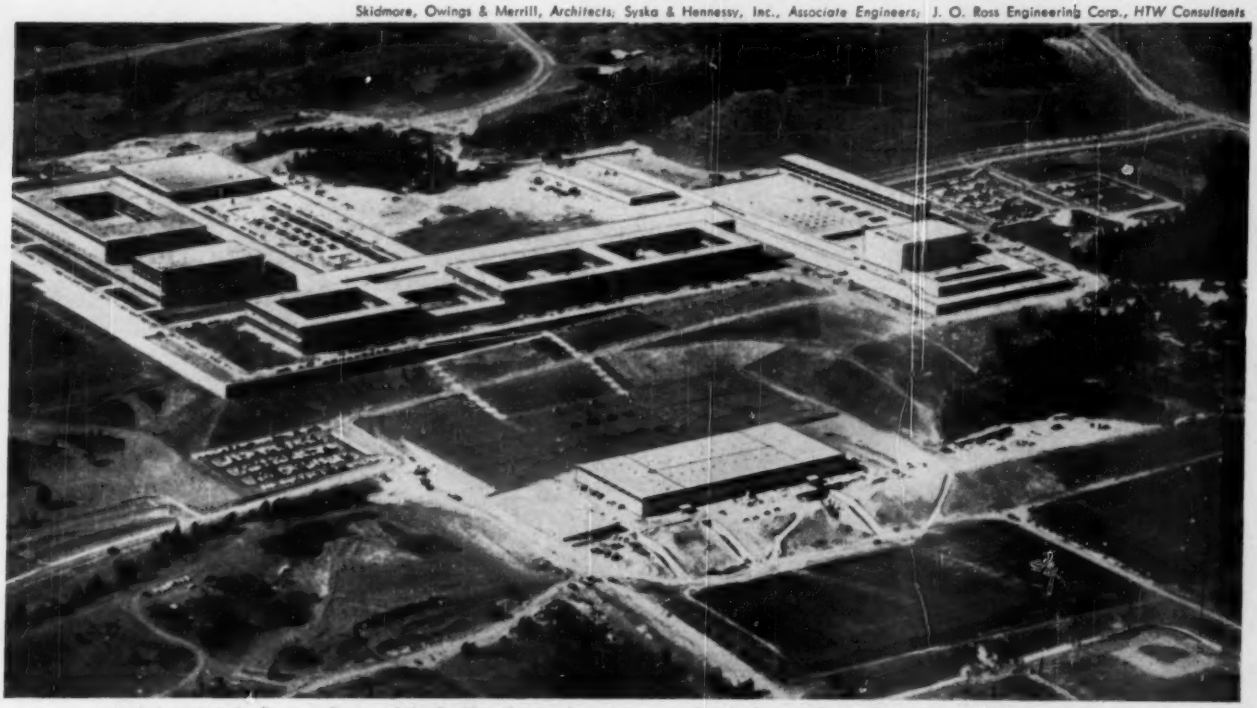
Selecting a heating system to service these widely-spaced buildings and facilities over the rolling and varying terrain required a type that permitted easy and economical pipe line distribution over individual closed circuits exceeding six miles in length—circuits which totally encompass nearly 15 miles.

Because of the irregular terrain and the large area, a steam system would have required a substantial number of steam traps and close attention to piping gradients. High temperature water, on the other hand, offered the advantages of smaller-sized piping with no pressure valves, and a smaller, more compact boiler plant than would have been required for steam ... with 10 to 20 per cent reductions in operating costs.

There are five C-E LaMont Controlled Circulation Hot Water Boilers serving the Air Force Academy. They are located in two separate boiler plants—3 in one and 2 in the other—and have been performing reliably, efficiently and with minimum operating attention since they were first placed in service in late 1957.

THE AIR FORCE ACADEMY

Skidmore, Owings & Merrill, Architects; Syska & Hennessy, Inc., Associate Engineers; J. O. Ross Engineering Corp., HTW Consultants



Nestled against the Rampart Range of the Rockies, the Academy presents an impressive sight from the air. Buildings, from left to right, are: Fairchild Hall, the Academic-Library Building, with Aerodynamics-Thermodynamics Lab and Mitchell Hall (Cadet Dining Hall) behind it; Vandenberg Hall, the Cadet Dormitory; Harmon Hall, the Administration Building; Arnold Hall, the Cadet Social Center; and Planetarium (dome at right). The parade ground stretches at left from sloping ramp. The Physical Education Building and athletic fields are at lower right.

COMBUSTION ENGINEERING

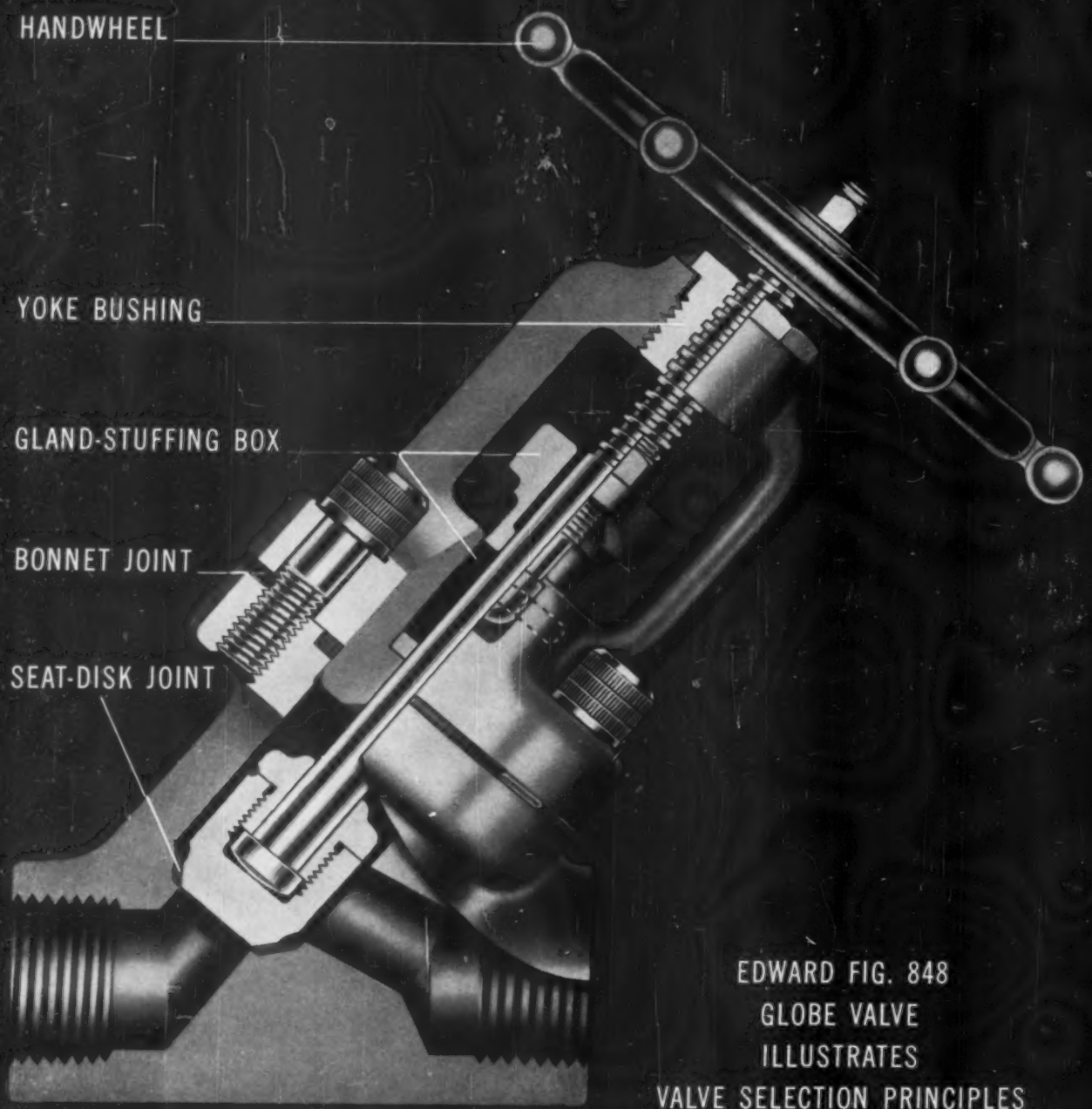
Combustion Engineering Building, 200 Madison Avenue, New York 16, N. Y.

Canada: Combustion Engineering-Superheater Ltd.

C-246

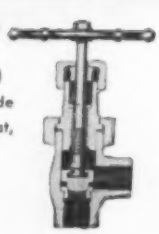
PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE

For more data circle 511 on Post Card



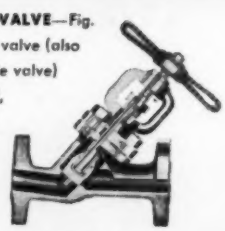
EDWARD FIG. 848 GLOBE VALVE ILLUSTRATES VALVE SELECTION PRINCIPLES

1 ANGLE VALVE—Fig. 2699, 600 lb at 900F (2000 lb WOG) with union bonnet, inside screw, replaceable seat, knobbed handwheel, and screwed ends. Sizes ¼" to 1".



2 UNIVALVE*—Fig. 2224, 1500 lb. at 1050 F (3600 lb WOG) or 2500 lb at 1050 F (6000 lb WOG) with outside screw, Impactor® handle seal-welded bonnet, integral seat and socket welding ends. Sizes to 2½".

3 BLOW-OFF VALVE—Fig. 641, straightway valve (also available as angle valve) 300 lb at 850 F, 600 lb at 850 F, 1500 lb at 850 F, with integral Stellite seat, flanged ends, bolted bonnet. Sizes to 2½".



What's New from Edward Valves

New Products . . . Solutions to Problems . . . Information on Steel Valves from Edward, Long-Time Pioneer in the Field!

HOW TO SELECT FORGED STEEL VALVES

When you need forged steel globe or angle valves (2½" and smaller) for high-pressure and/or high-temperature applications, you can save money on your installations as well as reduce future maintenance expense by making sure you select the proper valve. Here are a few suggestions.

VALVE CONSTRUCTION DETAILS
(See large illustration, opposite page)

Valve Handwheel or Handle should be large enough to operate valve easily. Wheel spokes help keep handwheel cool. Knobbed design permits tight grip even with greasy gloves. Impact type handle will be helpful in obtaining tight closure for valves 1½ to 2½ in.

Yoke Bushing material should be checked. High-strength aluminum bronzes are usually best. Look for ample thread engagement between bushing and yoke and between bushing and stem.

Gland-Stuffing Box—Stuffing box with bolted gland assures good packing compression; hinged bolts swing out of the way but don't get lost. Be sure to get stainless steel bolts for maximum resistance to rusting, and for easy adjustment even after years of service. Packing chamber should be deep and not excessively wide.

Bonnet Joint of bolted construction is easiest to work with. You can disassemble and reassemble with pocket-size tools. Union bonnet is compact and usually less expensive for smaller valve sizes, but is not recommended for high temperatures. Bonnet gasket of soft iron performs well in most services but spiral wound metallic-asbestos gaskets are superior in high temperature services. For extreme pressure-temperature services welded bonnet joints for permanent tightness are desirable. Seal-welded type bonnet has advantage over fully welded design because it permits disassembly and reassembly.

Seat-Disk Joint—An integral hard-faced seat is generally regarded as superior to screwed seat construction because it eliminates body-seat leakage and retains hardness under temperature. A hard faced disk or disk of special alloy is desirable in high temperature services; but 13 per cent chromium stainless steel is an excellent all purpose material below 750 F.

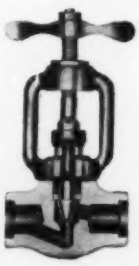
Other Features to Evaluate—Valve compactness is important because you frequently find small piping located in crowded quarters. Inclined bonnet globe valves are less likely to erode due to high velocities—have less pressure loss. Valves of "inside screw" design (stem threads below packing chamber) are usually lower priced and give good service where temperature is not too high and where line fluids are free of sediment. But, best design and materials are useless without experienced workmanship and rigid quality control.

VALVE APPLICATION SUGGESTIONS
First, determine whether a standard valve will do the job before ordering expensive special designs. (Your Edward Representative can help you decide.) Often a slight modification of a standard valve, or a combination of standard valves, will do the job. Here are some facts about types of standard valves and their application:

- For many services, angle valves (illustrated by valve #1) reduce installation cost, minimize pressure drop, improve operational convenience. All Edward forged steel stop and stop-check valves from ¼" to 2½" sizes are available in the angle version.
- For high temperature, Edward forged steel valves with seal-welded bonnets (#2) permanently maintain pressure tightness without periodic tightening of bonnet joints.
- For blow-off service, or wherever double valving is required, select sets of valves of the same basic type with hard-faced seating surface for dependability, longer life and interchangeability of parts (#3).
- For permanent tightness, select an instrument valve (#4) with corrosion-erosion resistant hard-faced seat or a valve with stainless steel body. Bonnetless design requires less maintenance.
- Piston-type check valve (#5), available with union, bolted, or seal-welded cover, is best for most services because it will seat tighter, has easily repairable seat face.
- Modern globe and angle stop valves (shown here) are more dependable than gate valves where repeated drop-tight closures are required, may be used for approximate flow regulation and moderate throttling.

YOUR EDWARD REPRESENTATIVE will be glad to give you the complete story on these features, plus the many other advantages of Edward valves—such as positive, pressure-tight backseats, self-centering disks, special stem and packing materials, and many others. Edward builds a complete line of cast and forged steel valves for pressures to 10,000 lbs. For additional information write to Edward Valves, Inc., 1202 W. 145th Street, East Chicago, Indiana. Subsidiary of Rockwell Manufacturing Company. Represented in Canada by Lytle Engineering Specialties, Ltd., 360 Notre Dame St., W., Montreal 1, Quebec.

4 INSTRUMENT VALVE—Fig. 952Y, 600 lb or 2500 lb at 850 F (6000 lb WOG) with swing bolted gland, socket welding ends, no bonnet joint. Sizes ¼" to 1".



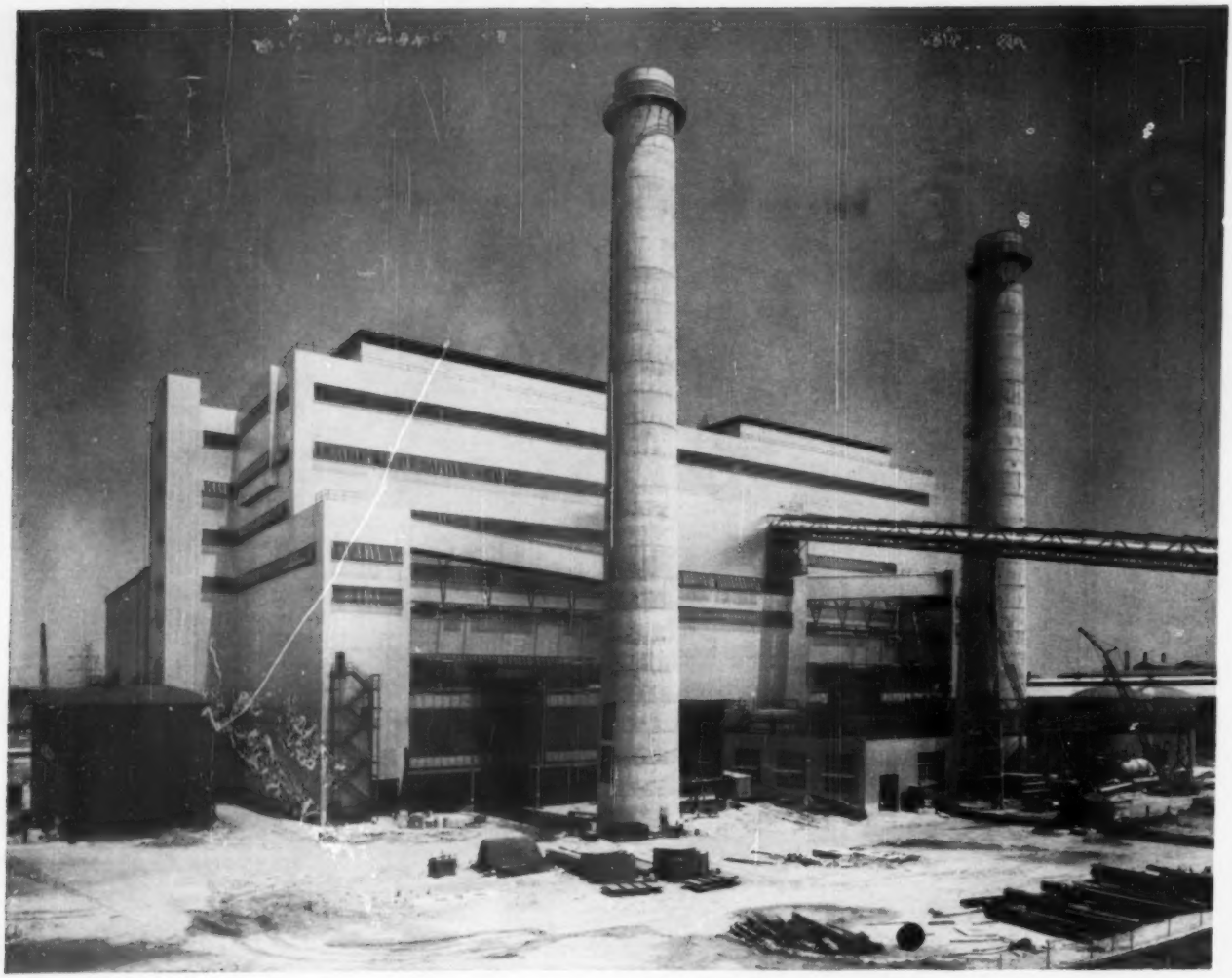
5 CHECK VALVE—Fig. 5538, piston type, 1500 lb at 1050 F (3600 lb WOG) bolted bonnet, screwed ends, integral Stellite seat. Sizes ¼" to 2".

*T. M. Reg. U. S. Pat. Off.

EDWARD STEEL VALVES
another line product by
ROCKWELL

Catalog 14 contains full data on the complete Edward line of forged and cast steel valves from ¼" to 18"; in globe and angle stop, gate, non-return, check, blow-off, stop-check, relief, hydraulic, instrument, gage and special designs; for pressures up to 10,000 lbs: with pressure-seal, bolted, union or welded bonnets, with screwed, welding or flanged ends.

For more data circle 512 on Post Card



Eddystone Station's Unit 1 has a capacity of 2,000,000 lb/hr at 5000 psig and 1200°/1050°/1050°/F . . . uses C-E Sulzer Monotube Steam Generator.

Vulcan Selective-Sequence system provides Eddystone Station with precision soot blowing

When Unit 1 of Philadelphia Electric's Eddystone Station went into operation, a Vulcan Selective-Sequence system was accurately controlling all soot blowing.

Selective-Sequence systems were chosen for both units 1 and 2 at this super-critical station because they assure positive, dependable boiler cleaning . . . make the most efficient use of the blowing medium.

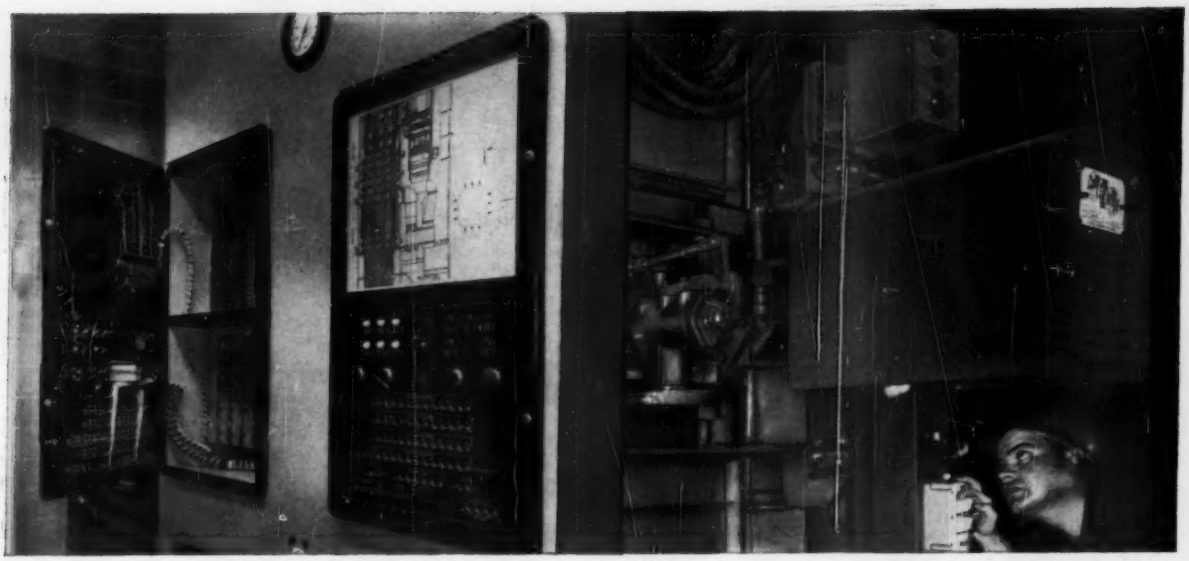
Vulcan Controller saves time. Without leaving the panel, the operator pushes a master button to place the system in sequential operation. He can see that each soot blower is operating in sequence for the proper interval with adequate pressure. He can modify the sequence to improve cleaning or conserve the blowing medium without time-consuming wiring and piping changes.

Vulcan long retractables speed cleaning. With dual-motor drive, Eddystone's T-30's clean uniformly; minimize the danger of tube cutting or erosion. Low rotating speed increases range and penetration of cleaning, decreases wear, eliminates whip, and permits proper cleaning with faster traversing speeds.

Half-'tracts with 19-foot travel, wall deslaggers, and air pre-heater controls are also used.

COPES-VULCAN DIVISION
BLAW-KNOX COMPANY, ERIE 4, PA.

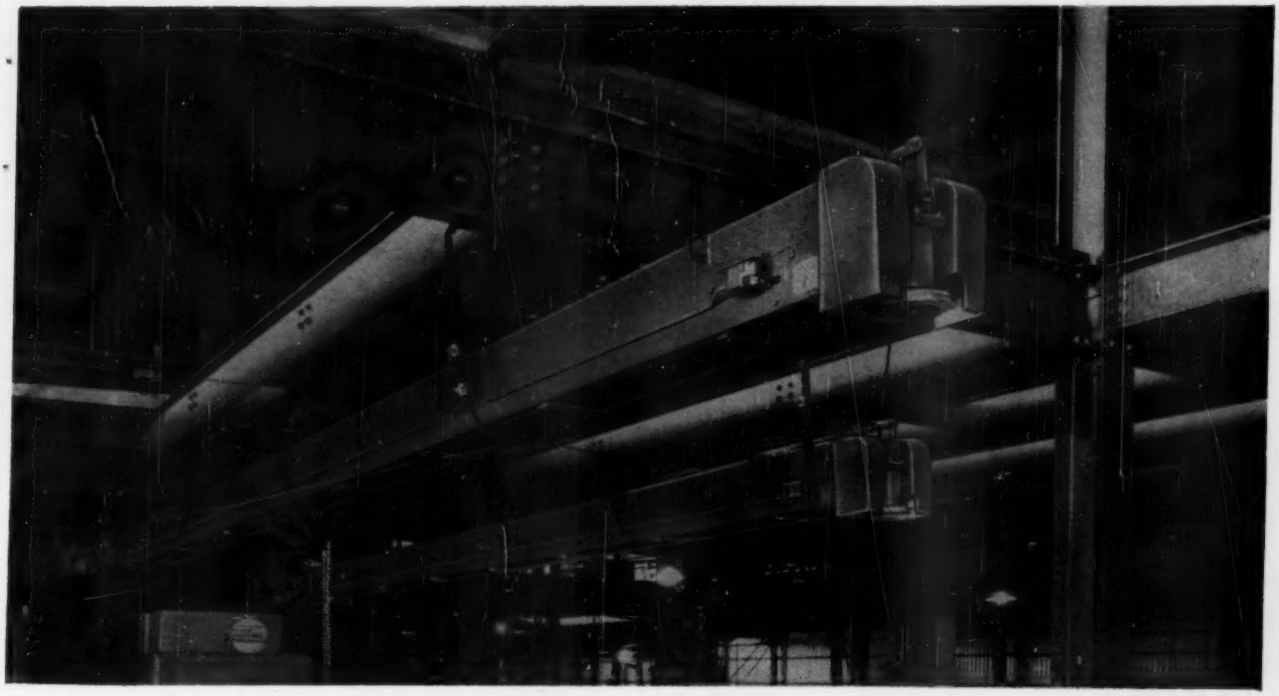
BLAW-KNOX

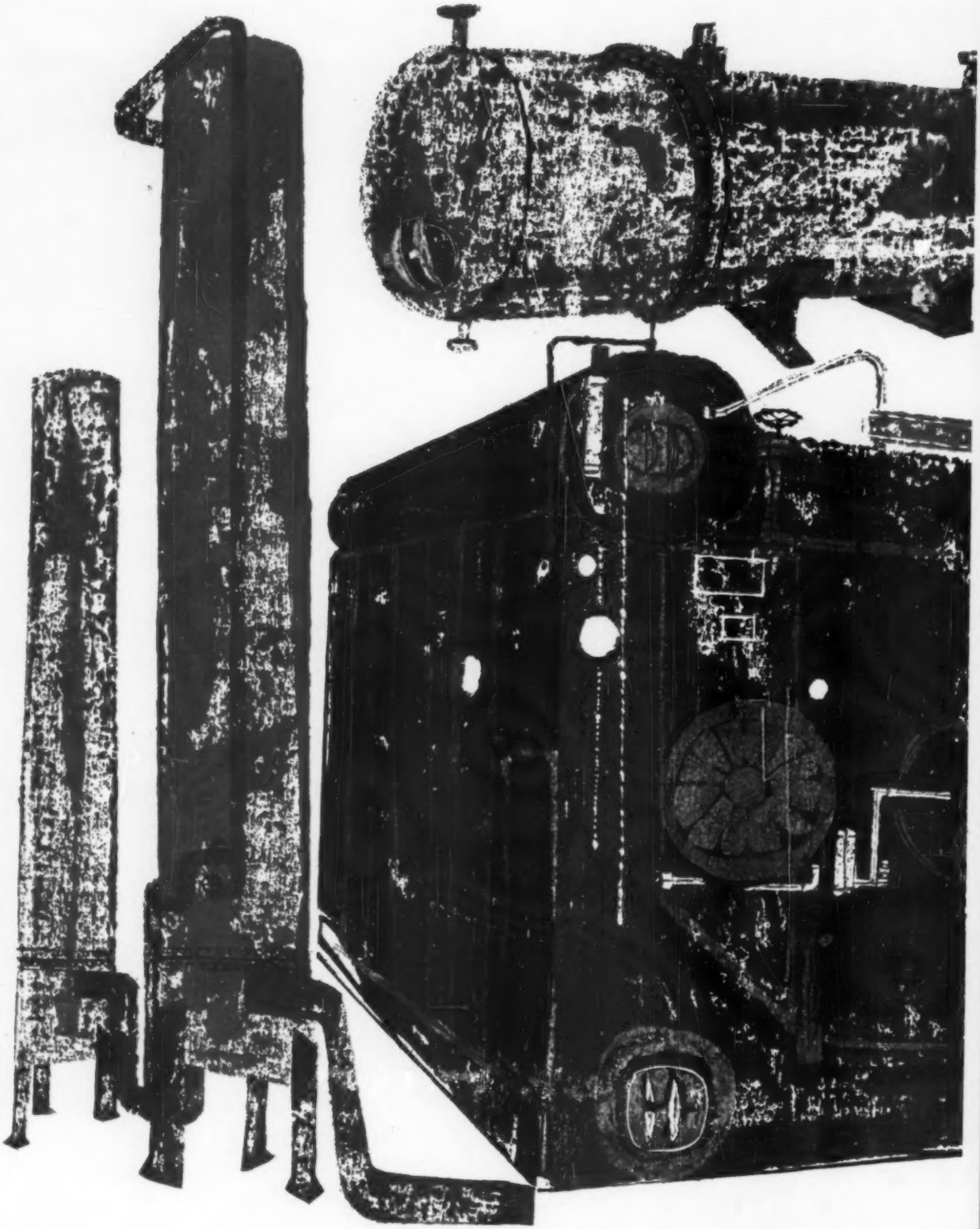


Panel provides centralized control of soot blowing at Eddystone. With the Vulcan SSC-120 Selective-Sequence controller, each blower can be operated four times during a schedule, or there can be four different schedules. The sequence can be varied by means of a jack board. Any soot blower can be operated at any point in the sequence by plugging one end of a patch cord into the blower jack, and the other end into the desired sequence jack. Write for Bulletin 1029.

Wall deslagger conserves steam generated at Eddystone by three special package boilers. High striking power of Vulcan RW-3E drives off gummy masses to assure high heat-transfer capacity, and uniform superheat and reheat temperature control. Dual motors are used: one speeds the nozzle to and from the blowing position, the other rotates it slowly for thorough cleaning. All parts are covered for protection, assuring long life with low maintenance. Write for Bulletin 1034.

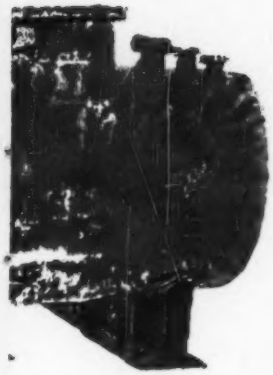
Vulcan T-30's have 30- and 37-foot travels. Motors are mounted at the boiler end to facilitate maintenance, yet away from heat of the boiler wall. Their placement avoids interferences. Write for Bulletin 1030.

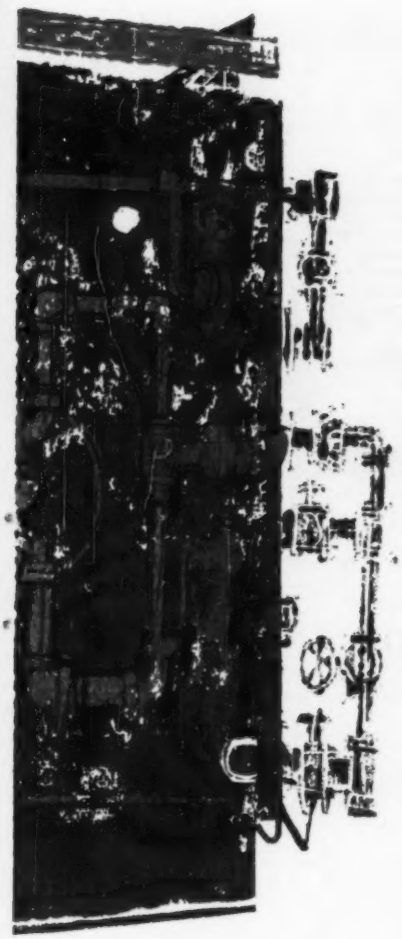




POWER PLANT PRODUCTS HEAT ENGINEERED BY FOSTER WHEELER:

Central Station and Industrial Steam Generators • Steam Condensers and Pumps • Pulverized Fuel Systems • Feedwater Heaters • Packaged Steam Generators • Cooling Towers • Nuclear Components





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At Foster Wheeler *extra thoroughness* is standard procedure. FW engineers are more than just designers and builders of equipment. They are also men with experience in the overall application, operation and servicing of power plant equipment. In knowing a little more about the whole plant, they are better able to produce efficient, rugged, easy-to-operate equipment.

This *extra thoroughness* also refers to the conscientious work of FW shop men and technicians who are familiar with equipment end-use. They never forget that operating conditions are often more severe than those created in standard shop tests.

And this *extra thoroughness* is further demonstrated in the training and supervision of the people responsible for product design and fabrication.

The result... better engineered and better built power plant equipment! Prove this to your satisfaction by addressing an inquiry to Foster Wheeler Corporation, 666 Fifth Avenue, New York 19, New York.

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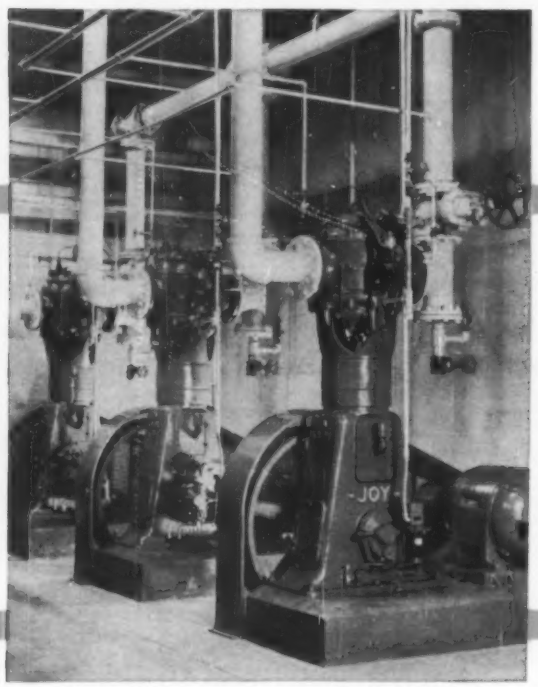
FOR OIL-FREE AIR WITHOUT EXCESSIVE MAINTENANCE

JOY WGO-9 COMPRESSORS



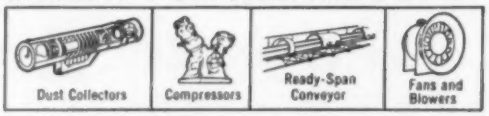
A continuous supply of oil-free air is guaranteed by this multiple installation at a midwestern container factory. Vertical design means reduced maintenance . . . the piston ring need never be rotated.

This Joy WGO-9 supplies air free of contamination because it uses no lubrication in the cylinder. Lubrication is eliminated by the use of carbon-graphite or teflon piston rings. Exclusive piston ring design (patents pending) gives ring life of 8000 operating hours, and more. Joy has more than 20 years of experience with these special compressors, and as a result, has developed 14 sizes of the WGO-9 to meet your every requirement. Capacities run from 95 cfm—15 hp, to 939 cfm—75 hp. For larger volumes of oil-free air you can specify the WN series, up to 600 hp, 3696 cfm.

Get complete details on the Joy WGO-9, one of a complete line of compressors for industry. Write for free bulletin 337-56C.

337-607

AIR MOVING EQUIPMENT FOR ALL INDUSTRY



JOY

Joy Manufacturing Company
Oliver Building, Pittsburgh 22, Pa.

In Canada: Joy Manufacturing Company (Canada) Limited, Galt, Ontario

For more data circle 515 on Post Card

HELPFUL BULLETINS

MECHANICAL POWER TRANSMISSION

101 V-Belt Drives — This comprehensive manual contains 68 pp of engineering data for design of multiple V-belt drives with company's method of "tempered" construction designed to increase belt horsepower rating, minimize stretch, increase resistance to abrasion and shock, and add flexibility. Contains photos, drawings, charts, tables and other data covering all phases of selection and design. R. & J Dick Co., Inc.

102 Variable Speed Belts — Catalog VSB-1 is a 32-pp belt selection guide for variable speed belt users. In addition to ratings, sizes and engineering data, it provides such reference information as alphabetical listing of applications, numerical listing of manufacturer's parts numbers, numerical listing of applications, and variable speed cross reference tables. Maurey Mfg. Corp.

103 Speed Reducers — Catalog 590 is a 65-pp supplement to company's 186-pp general catalog on stock gears and speed reducers and provides complete engineering data, dimensions and application selection charts on the Hi-Line series fin and fan cooled reducers. Catalog is pocket size and designed for convenient location of engineering data. The Ohio Gear Co.

104 Planetary Gears — Eight-pp Bulletin 2401 covers planetary and star gears, used for boiler and feed and circulating water pump drives, compressor and blower drives, and as drives for turbines and internal engines. Includes cutaway drawings, information on construction details, capacity and selection curves, and tables of dimensions. De Laval Steam Turbine Co.

105 Spring Loaded Pulleys — Bulletin SL-1 describes spring loaded pulleys and adjustable motor bases which provide for both fixed centers and varying centers. Selection charts, specifications and engineering data given. Maurey Mfg. Corp.

106 Motion-Control Sheave — Eight-pp Bulletin 8102 features variable-speed sheaves with resilient cam-follower design which will hold a constant driven speed under varying torque loads. Cutaway photos and diagrams showing construction are included, as well as tables of selection data. T. B. Wood's Sons Co.

107 Roller Bearings — Six-pp Catalog 359 describes heavy duty roller bearings featuring a one-piece cage design which permits use of bearings at higher speeds. Includes design data, load capacity, dimensional and mounting guide, and information on installation and lubrication. The Torrington Co.

108 Pillow Block Bearing — Comprehensive information on pillow block bearings and mountings, their applications, variations, lubrication and installation is provided in 40-pp Catalog 51-59. Described and illustrated is an extensive line of sleeve-type, self-aligning pillow blocks — single-bolt mountings, wall bearings, pedestal bearings, tri-arm bracket assemblies, plain and cushioned flange mountings. Triangle Mfg. Co.

New and revised publications reviewed on these pages offer help on operating and maintenance problems. To order, use the handy Reader Service Cards provided on pages 101 and 102.

109 Bearing Blocks, Takeups — Detailed information on babbitted, bronze and plain bore bearing blocks and takeups is presented in 16-pp Book 2707. Design features and advantages, illustrations and descriptions of each type of block and takeup and its class of application are featured. Link-Belt Co.

COMPRESSORS

110 Centrifugal Compressors — Three styles of single-stage scroll casing compressors are illustrated and described in 12-pp Bulletin 16B6048C. Includes description of bearing and shaft seal arrangements for the three styles, an impeller chart, and performance data. Allis-Chalmers Mfg. Co.

111 Process Compressors — Features and advantages of company's balanced/opposed process compressors for refining, chemical and petrochemical industries are detailed in 46-pp Bulletin 160. Balanced/opposed design principle is illustrated and described, as well as component features of the compressors, and dimensions, specifications, and photos of typical installations are included. Clark Bros. Co.

PIPING FITTINGS

113 Pipe Thread Fittings — Advantages of company's pipe thread fittings designed to eliminate positioning problems, leakage and overtightening damage are detailed in this product bulletin. Common types of positioning, distortion, alignment, reworking and leakage problems and their solutions are illustrated, and installation and dimensional data given. Tru-Seal Div., Flick-Reedy Corp.

114 Cast-Aluminum Coupling — Described in Bulletin PF-1 is a cast-aluminum coupling for joining extruded aluminum steam-traced piping. Drawings illustrate three basic types of couplings available. Alcast Fittings.

115 Fittings and Hose — Condensed Catalog C-301 contains 16 pp of comprehensive listings of brass and steel tube fittings, tube working tools, hose, hose ends and assemblies most frequently used in hydraulic and pneumatic systems. Detailed selection tables are included. The Weatherhead Co.

116 Tube Fittings Finder — Bulletin 4306-B1 offers condensed information on selection of proper fittings for various service and installation requirements. Includes shape charts for six types of industrial tube fittings and illustrations of tube-working tools. Parker Fittings and Hose Div., Parker-Hannifin Corp.

117 Self-Sealing Coupling — Features and advantages of a quick connect-quick disconnect coupling designed for "no-spill" service are illustrated and described in Catalog 280B. Cutaway drawings, dimensional data, and specifications are included. Snap-Tite, Inc.

HEATING, VENTILATING

118 Propeller Fan Heaters — Design and construction features of company's propeller fan unit heaters are described in 12-pp Bulltin 1301-B. It contains steam and hot water capacity data, conversion factors and basic formulae, typical quietness levels and piping arrangements. Dunham-Bush, Inc.

119 Heating, Ventilating Supplies — Detailed selection information for air conditioning, ventilation, refrigeration and heating supplies and equipment is presented in this 38-pp 1959 Estimating Catalog. Includes capacity and dimensional data on fans, roof ventilators, heating and ventilating units, air conditioning units, heating and cooling coils, condensing units, evaporative condensers, cooling towers, unit coolers, air heaters, air cooled condensers, control valves and accessories. M. Blazer & Son.

ELECTRICAL

121 Station Arresters — Bulletin GEA-6794A, 12 pp, describes features, operation and characteristics of station arrestors for high and extra-high voltage applications. Publication includes photos, oscillograms of long-duration, discharge current withstand tests, cutaway and line drawings, flexibility rating tables, application data and dimension charts and tables. General Electric Co.

122 Enclosed Fuse Cutouts — Twelve-pp Bulletin GEA-6208B gives pertinent information on operation, features and characteristics of enclosed fuse cutouts rated 5.2 kv, and 7.8 kv, 50 and 100 amp, with gas loadbreak device available on 100 amp units. Includes photos, cutaway, dimensional and line drawings, and application data tables. General Electric Co.

123 Oil-Filled Cutouts — Bulletin GEA-6825 contains 28 pp of detailed information on the application and operation of oil-filled cutouts for fusing and switching operations. Topics covered include pole-type, pothead-type, and subway-type cutouts, oil-filled cutout data, gang-operated switching mechanisms, switching mechanism data, metal-enclosed assemblies, assembly data, and interchangeable fuse links. General Electric Co.

124 Low-Voltage Switching — Twenty-pp Electrician's Manual RM-610 contains an introduction to low-voltage switching. Explains how company's remote-control switching works electrically, how components are mounted, how to plan a layout, and gives installation instructions. Manual is fully illustrated with pictures and easily understood diagrams. Remcon Div., Pyramid Instrument Corp.

125 Metal-Clad Switchgear — Eight-pp Bulletin 3-450 describes drawout metal-clad switchgear designed to serve the higher capacity requirements of modern power systems. Construction features are illustrated and described, and dimensions and typical arrangement diagrammed. Federal Pacific Electric Co.

126 Power Panelboards — Bulletin VBP-470 contains 18 pp of information on features, design and operation of company's fusible Vacu-Break power panelboards. Contains circuit and dimension data, trim data, and suggested specifications. Bulldog Electric Products Div., I-T-E Circuit Breaker Co.

127 Overload, Fault Currents — Sixteen-pp Section 7 of company's aluminum conductor engineering data series discusses overload and fault current limitations of bare aluminum conductors. Includes description of fault and overload currents, along with graphs showing maximum allowable time for various high value emergency or short circuit currents. Aluminum Co. of America.

128 Versatile Voltmeter — This illustrated bulletin covers features of Model R-2 Voltmeter designed for such applications as measuring the regulation of power supplies, the resolution of potentiometers, and the linearity of amplifiers. Includes specifications and a schematic diagram of the unit. Southwestern Industrial Electronics Co., Div. Dresser Industries, Inc.

129 Silicone Rubber Insulation — Bulletin CDS-208 lists outstanding insulating properties of company's silicone rubber and discusses major application areas in which silicone insulated cable has proven its performance. Includes cost comparison data, as well as table of comparison data between silicone rubber and other types of insulation. General Electric Co.

ENGINES, GENERATORS

130 Dual Fuel Engine System — Bulletin EG-B46 describes features and advantages of company's dual fuel engine, essentially a diesel engine with a simplified gas-fuel system, and special controls for regulating quantity of gas admitted. Describes four basic elements of system. Enterprise Engine & Machinery Co.

131 Electric Generators — Eight-pp Catalog F-146 describes gasoline and diesel engine-driven high-capacity electric generating sets. Specifications for both engine and generator are given, along with capacity data, dimensions and weights. D. W. Onan & Sons Inc.

OTHER EQUIPMENT

132 Molded Packings — Features and advantages of company's automatic packing made of rings molded into V cross sections are detailed in 8-pp Bulletin PY-959. Engineering data includes formulas for computing stack heights, and schematic diagrams and cutaway view installation drawings show typical rod and piston seal applications and assemblies. Greene, Tweed & Co.

133 On Water Clarification — Eight-pp Technical Reprint T-176 discusses the subject of clarification of high color-low turbidity waters. Covers coagulants and aids to be considered for this type of water and design and operating considerations for an adequate clarification unit which can meet the problems presented. Graver Water Conditioning Co.

134 Fluid Power Equipment — Bulletin 10051-H contains 16 pp of detailed information on fluid power equipment, including pumps, motors, transmissions, servo components, cylinders, and valves. Photos and cutaway views illustrate details of operation and design, and tables list specification data. The Oilgear Co.

135 Volumetric Feeder — Eight-pp Form 161 describes volumetric belt feeders designed to provide unrestricted coal flow to pulverizers and to cyclone burners. Includes data on types, sizes, capacities, and illustrates belt changing method. Stock Equipment Co.

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136 Sewage Plant Treatment — Technical Paper 138 discusses problems in use of sewage plant effluent for boiler and cooling purposes. Reports on how sewage plant effluent can be used satisfactorily in recirculating cooling systems and as boiler makeup provided it is adequately treated to avoid operating problems such as organic growths, deposits and corrosion in cooling systems and foaming, carryover and ammonia corrosion in boiler and steam systems. Betz Laboratories, Inc.

137 For Chemical Cleaning — Technical Bulletin 102, about 16 pp, presents application and other information on company's products for chemical cleaning. These include formulas tions for power plant cleaning, stainless-steel cleaning, aluminum and aluminum alloy cleaning, alkaline derusting and paint stripping, general cleaning, others. Also provided is chart of corrosion rates. Chas. Pfizer & Co., Inc.

138 For Fire Protection — Folio 1 is a 12-pp revised booklet on fire extinguishing systems and equipment. Lists principal causes of large-loss fires, advantages in use of carbon dioxide, and examples of extinguishing installations in steel, general manufacturing, electrical and other industries. Shows typical systems for protection of generators, flammable liquids, paint spray areas, quench and dip tanks, pumping operations etc. Also describes components and control of systems. Cardox Div., Chemetron Corp.

139 Surface Condensers — Design and construction of company's surface condensers is detailed in 16-pp Bulletin C-10. Sectional drawings, photos, tables, condenser performance data, and heat transfer determination chart are included. Elliott Co., Carrier Corp.

140 Chemical Product Review — This 44-pp compilation lists properties and uses of company's industrial, pharmaceutical, and agricultural chemicals currently produced, including established products and developmental items. Features an expanded section on plastics and coatings, as well as sections on oxazolidinones, automotive chemicals and textile fibers. The Dow Chemical Co.

Postage-free cards for ordering catalogs are on page 101. You may also use the cards to order literature mentioned in the ads.

141 Area Floodlighting — Planning for lighting of parking areas, construction sites, other open areas is detailed in 16-pp Bulletin 2719. Contains reference guides for selecting incandescent or mercury floodlights, general purpose or heavy duty types, and for determining how many floodlights are needed based on size of area to be lighted, as well as footcandle charts, installation diagrams. Crouse-Hinds Co.

142 Condensate Flow Regulator — Bulletin 300-M describes a condensate flow regulator for drainage of heating and processing units operating continuously at pressures up to 60 psi. Tables furnished with the bulletin give the capacity of condensate handled under different pressure differentials and other conditions. Stickle Steam Specialties Co.

143 For Non-Destructive Testing — This bulletin covers briefly the wide range of reliability tests available in company's non-destructive test systems. Shows why many non-destructive test problems can be solved by one or another of these systems. Magnaflux Corp.

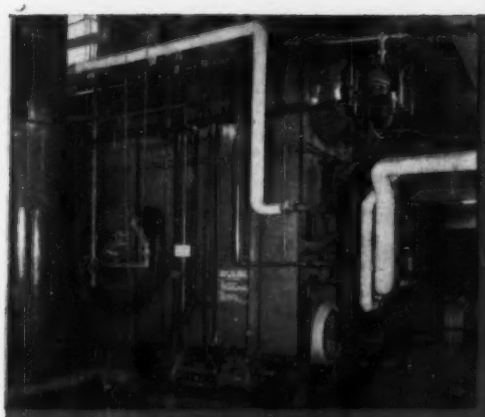
144 Seals and Fasteners — Sixteen-pp Catalog 359A illustrates and describes high-pressure, vibration-resistant seals and fasteners. Tabular data, specifications, brief descriptive text and engineering drawings are provided. Products covered include Hexseals, Seelskrews, Seelbolts, and Seelrivits. RubRglas-Seel transparent and flexible wide-angle boots for sealing circuit breakers and indicator lights are also described, as are miniaturized and ruggedized armored power connectors. A. P. M. Corp.

145 Corrosion Resistant Tube — This 6-pp bulletin describes tubing and pipe made of a corrosion resistant alloys, and includes tables of comparative resistance to various corrosive media such as hydrochloric, phosphoric, and sulphuric acids, nitric and oxidizing acid mixtures, organic acids, chlorine and hypochlorites, and acid salt at specified concentrations and temperatures. Physical and mechanical properties and other data included. The Carpenter Steel Co.

146 Compressed Air Dehydrator — Compressed air dehydration and filtration accomplished by a refrigerated condenser-type filter is explained in Bulletin F-100. Includes flow chart showing details of operation, component parts, installation drawings, product specifications and performance data. Hankison Corp.

147 Corrosion Control Method — This technical data sheet discusses the Dianodic method of corrosion control and its use in open recirculating cooling water systems. Variations of the Dianodic method to meet specific requirements and cope with variables that enter into the corrosion problem are covered. Betz Laboratories, Inc.

Editor's Note: More bulletin reviews — dealing with various aspects of automation — will be found in a special section at the back of this month's POWER ENGINEERING.



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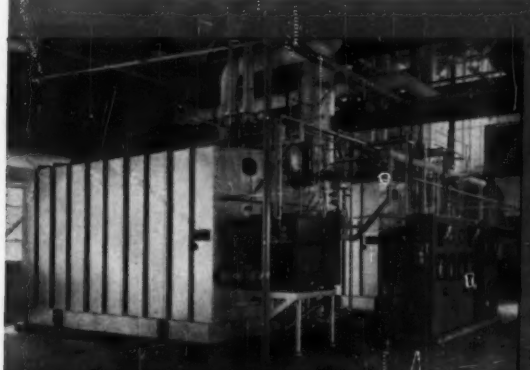

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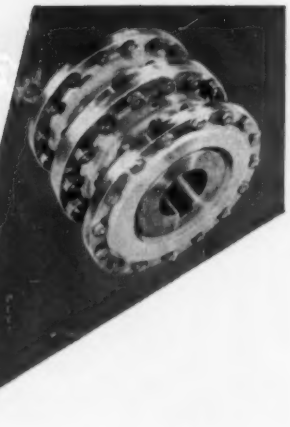

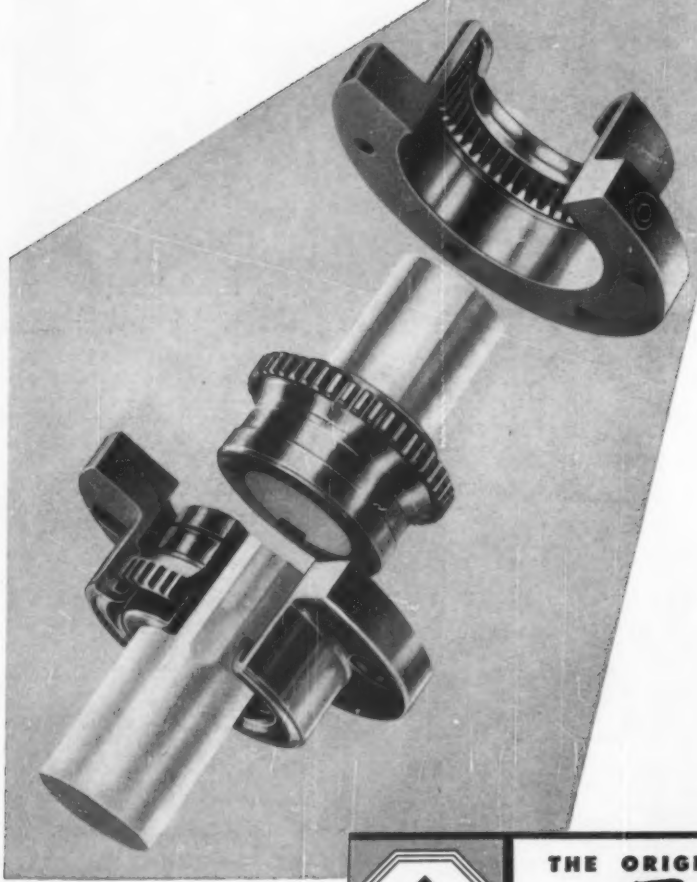

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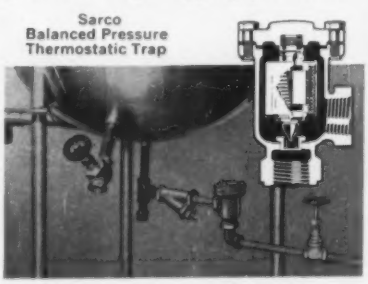
EXAMPLE 1: Outside Tracer Lines: A tough set of requirements

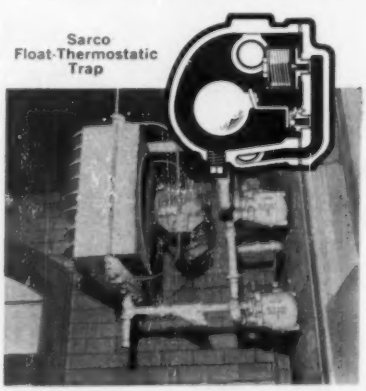
One of the most demanding sets of requirements a steam trap has to face is found in *outside steam tracing*. The trap must not only rid tracer lines of condensate and air immediately they're formed, but it must do so under exacting conditions. Pressures on each trap may vary widely. Installations may be remote and inaccessible to service. Water hammer may be a constant threat; freezing may be a hazard. Only the unique Thermo-Dynamic trap takes all these demands in stride. The Sarco TD-50 operates perfectly *without adjustment* through its full pressure range of 10-600 psi. It's virtually immune to water hammer and won't freeze when installed with a free discharge. Maintenance is, therefore, negligible. Compact, requiring no external support, the TD-50 is just about the easiest trap in the world to install. Once it's installed, you can forget it. You can count on an extremely long, trouble-free service life with minimum maintenance attention.

More closely than any other model, the TD-50 approximates an all-purpose trap. However, special application requirements might dictate the use of another type of Sarco trap. Sarco engineers stand ready to help you solve any trapping problems.



EXAMPLE 2: For steam jacketed process kettles: a trap that operates immediately on start-up and self adjusts to both low and high pressures

When a large steam-jacketed process kettle starts up, the condensate load is high, and all air in the jacket must be released quickly. At this stage, however, the jacket pressure is low; yet it builds up rapidly as the process continues. Because a SARCO No. 9 Balanced Pressure Thermostatic Trap is wide open on start-up, it releases initial air and condensate without the need for a bypass. And because it is self-adjusting, it works just as efficiently during the first processing stage when the jacket pressure is high. There are no seats to change for various working pressures. You can see why it is the obvious choice for steam jacketed process kettles.



EXAMPLE 3: How to prevent water-logging in unit heaters and blast coils

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ously. Pressures may vary widely under automatic temperature control and so may the load because of variable demand. A trap to handle this application must adjust itself instantly to pressure and load charges. The most precise answer to this problem is the SARCO Float and Thermostatic Trap—and here's why: it releases air on start-up and during running, and, because it discharges condensate continuously, it does not set up in the system violent pressure changes that would upset close control.

Sarco Liquid Expansion Trap

EXAMPLE 4: How to release low temperature condensate

When condensate cannot be returned to the boiler feed tank either because of distance or because it may be contaminated, it's economical to utilize some of the sensible heat as well as the latent heat of the steam.

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Sarco Bucket Trap

EXAMPLE 5: Economic handling of Water Hammer and Corrosive Conditions

In applications in which water hammer or corrosive conditions are encountered but in which low pressures or extremely high back pressures preclude the use of the Thermo-Dynamic trap, the Sarco Inverted Bucket Trap is recommended. While the Sarco I. B. is not exactly a fuel miser, its relatively rugged construction will withstand considerable water hammer; and, when it is fitted with stainless steel internal parts, it offers excellent resistance to corrosion.

* * *

CONCLUSION: The right application is the economical installation

When you choose steam traps that serve their purpose without frequent adjustment, and without maintenance or replacement problems, you save on down-time, man-hours, spare parts, and production slowdowns.

You can get the money-saving solution to every trap selection problem by consulting Sarco. You get impartial solutions, because only Sarco makes all 5 types of steam traps: Thermo-Dynamic*, Thermostatic, Float Thermostatic, Liquid Expansion, and Bucket.

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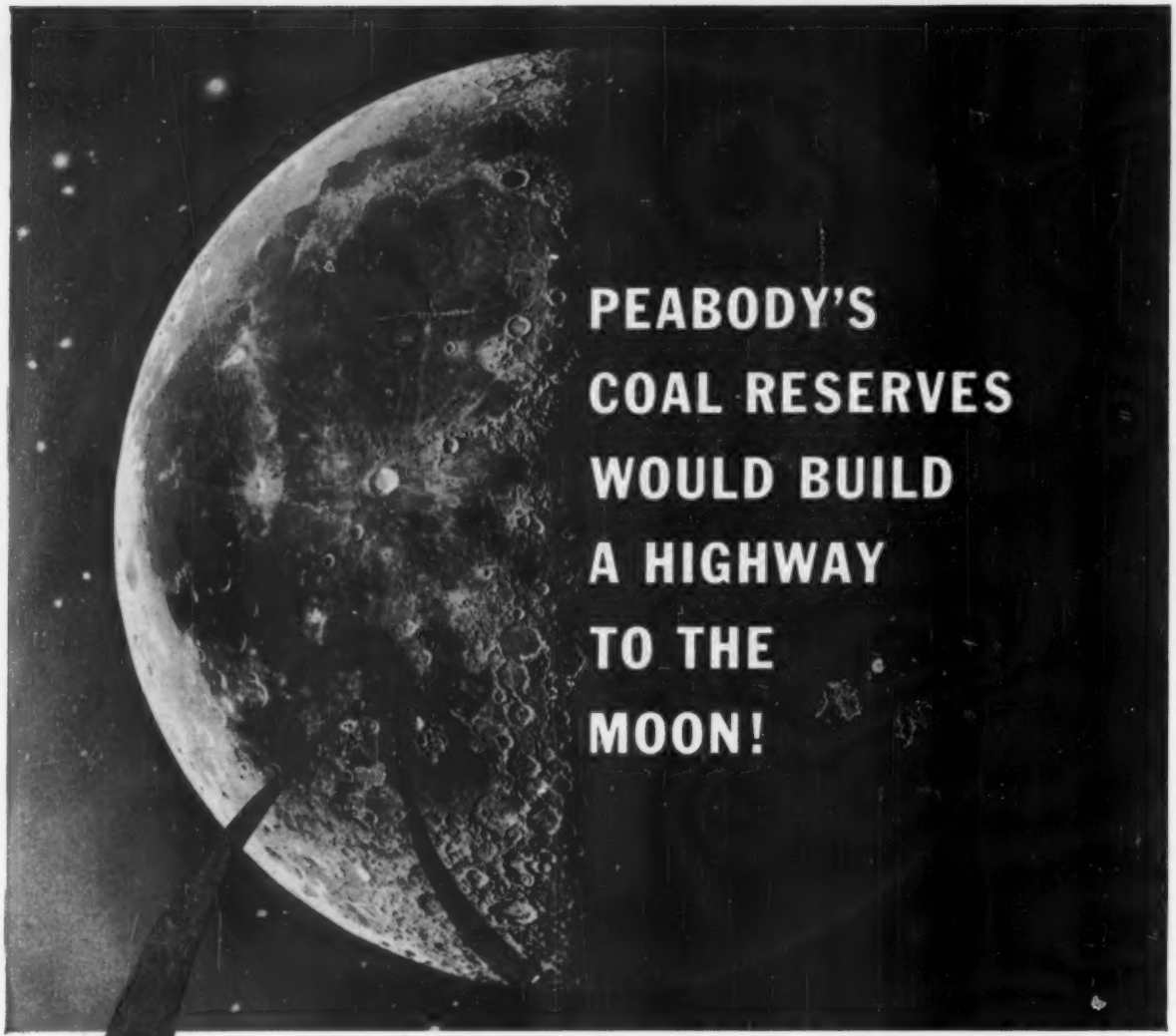

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A POWER ENGINEERING FEATURE FOR UTILITY & MAJOR INDUSTRIAL EXECUTIVES

A. W. Kramer, Editor

A Periodic Report on Atomic Energy Development Throughout the World Published by Technical Publishing Co.

January 1960

Someone has said, "Everybody talks about the atom; however, it is the neutron that is really important." This, of course, is true; if it were not for the neutron, there would be no atomic industry—no atomic bombs, no fallout problems, no nuclear power development.

It may seem strange to the layman that this tiny, unrevealing, and somewhat transient particle could have exerted such a profound effect on all our lives in so short a time. Only 27 years ago the neutron was unknown. Its existence, however, had been suspected as early as 1920, when several physicists predicted the possible existence of a particle possessing no electric charge. This particle, named the "neutron" by W. D. Harkins, was discovered by James Chadwick in England in 1932.

The rapid rise in importance of the neutron is typical of the rapid development of atomic and nuclear physics in modern times. Less than 50 years ago "nucleus" was a word which was unknown in the field of physics. Now, it describes a great industry, and in recent years we have staged important international conferences, attended by scientists from all over the world, organized expressly to discuss the interactions of neutrons with the nucleus of the atom. The tremendous intellectual and scientific advances which have occurred in the years of this century are most dramatic.

Today, we not only are very familiar with the structure of the atom as a whole but the structure of the nucleus itself is revealing itself, and some light is being thrown on the structural details of even the neutron. Simple as the neutron appeared to be when it was first discovered, it is now known to be a complex object, and its behavior is sometimes very confusing. Although the neutron's most significant properties have been known ever since it was discovered, there are many other aspects of its behavior that are still not understood.

No Charge. The neutron differs from most other nuclear particles in that it has no electric charge. Its mass is very nearly equal to that of the proton, but electrically it is completely neutral. Normally neutrons form a part of the nuclear structure of all atoms, except the hydrogen atom. As is well known, the nucleus of the hydrogen atom consists of a single proton. All other nuclei are made up of varying proportions of protons and neutrons, the heavier atoms having a preponderance of neutrons in their nuclei. It is not certain, however, that the neutron possesses the same individuality when it is part of the nucleus that it does when it is free, that is, when it exists away from the nucleus. Actually, outside of the nucleus, the neutron is unstable—it can exist for only about ten minutes. The reason for this instability can be found in the neutron's mass as compared to the mass of the proton.

As already indicated, the mass of the neutron is not exactly the same as the mass of the proton—the mass of the neutron is about 0.1 per cent greater than that of the proton. This difference in mass may seem very slight, but it led to important consequences; it opened the possibility that the neutron would be unstable and that it would disintegrate spontaneously into a proton, and at the same time release energy.

According to the Einstein mass-energy equivalence principle, the neutron, by virtue of its greater mass, can be considered to possess more energy than the proton. Thus, in changing to a proton, some of the mass of the neutron disappears and is emitted in the form of energy in accordance with the Einstein equation, $E=mc^2$.

The Einstein equation tells us how much energy appears in such a nuclear disintegration, but it does not disclose the form in which it is released —whether as electro-magnetic radiation (light or x-rays) or as kinetic energy of emitted particles. In the case of the disintegration of the neutron it seemed almost certain that an electron would be emitted since that would leave the expected proton with the required positive electric charge. It was obvious from the beginning that this would be the simplest of all nuclear disintegrations.

The Neutrino. Experimental investigation proved that this theory was correct. Neutrons were found to disintegrate spontaneously into a proton and an electron, but this proved to be not the whole story. The measured kinetic energy of the electron varied widely in different disintegrations and the direction of its motion also was difficult to account for.

In these experiments, as shown in Fig. 1, a beam of neutrons from a nuclear reactor is passed between two detectors or counters, one sensitive to protons, the other to electrons. These detectors are placed at right angles to the direction of the neutron beam so that at times a proton appeared in the proton detector at the same time as an electron was registered by the electron detector. This proved that the neutron did disintegrate into a proton and an electron as expected. It was found, however, that the two particles did not travel in exactly opposite directions, which they should have done if the disintegration gave rise to only two particles. This was necessary to satisfy the law of conservation of momentum. It was found that the electron detector had to be placed at something less than right angles to the neutron beam, as shown in Fig. 2.

The behavior of the particles in these experiments indicated that either they did not satisfy the law of conservation of momentum or that energy was being released in some other way The only way this could be explained was by assuming that some of the energy needed to satisfy the Einstein law was being carried away by a third particle. However, no third particle was ever detected nor was the emission of energy in any other form. Because no other explanation was forthcoming, the somewhat fantastic assumption was made that the energy was being carried away by a third particle—one having neither mass nor electric charge. Enrico Fermi named this hypothetical particle the "neutrino"—the Little One. As indicated in Fig. 2, although undetectable, since it has zero mass and zero charge, the path of the neutrino is drawn in such a way that the vectors representing the energies of the particles satisfy the required energy balance. At the time this bold hypothesis was made there was little reason to believe that the existence of a massless, chargeless particle could ever be detected, but elaborate experiments in later years actually succeeded in detecting the neutrino.

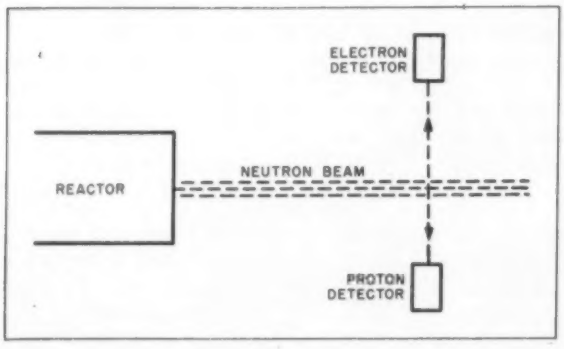


Fig. 1

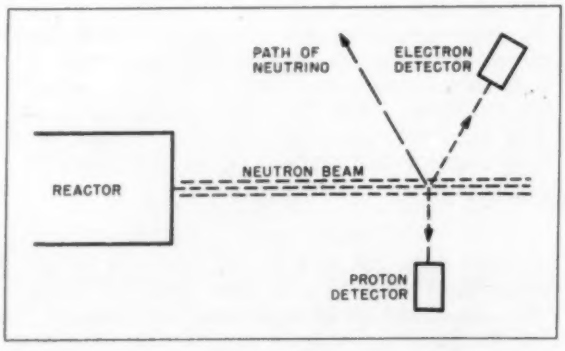


Fig. 2

By means of the Einstein equation, the amount of energy given up in the transformation of a neutron into these other particles could be calculated, and this came out to be around one million electron-volts. In subsequent experimental work the energy produced in the neutron disintegration process was measured and it proved to be exactly the same for each disintegration, provided the energy carried away by the neutrino was taken into consideration. The measured value was just about one million electron-volts, confirming the calculated value. In the experimental work it was possible to compare the number of neutrons in the beam from the reactor with the number that disintegrated, and this ratio gave the neutron an average life of ten minutes.

Considering this transient existence of the free neutron, it is obvious that the neutron must be quite different in its behavior outside the nucleus of the atom than it is inside. If the neutron inside the nucleus had a life of only ten minutes, all the neutrons in the nucleus would turn into protons, and matter would not be stable. Evidently, inside the nucleus the neutron is profoundly influenced by other particles. It is quite possible that inside the nucleus both the neutrons and the protons have little stability of form and that they are continually changing from one into the other, the total number of each, however, remaining the same.

Quantum Considerations. In trying to visualize the behavior of the neutron and its interaction with the nuclei of atoms we are faced with great difficulties because neutron behavior, like all phenomena in the sub-atomic world, is subject to the laws of quantum mechanics, where the impossible is more than likely to happen. In this strange world of the quantum, the neutron in common with other nuclear particles takes on different aspects, behaving sometimes as a particle, sometimes as a wave, often exhibiting the characteristics of both at the same time.

According to quantum or wave mechanics, any sub-atomic particle or quantum of radiation, such as light, exhibits a dual nature. Light is ordinarily regarded as having the characteristics of waves, but as shown by Max Planck early in this century, light also behaves as though it consists of small particles or bundles of energy—quanta. Similarly, sub-atomic particles such as neutrons behave as though they are waves; indeed, they have a definite wave length depending upon their energy. This wave length is given by a simple formula:

$$\lambda = \frac{h}{mv}$$

where λ (lambda) is the wave length in cm, m, the mass in grams; v, the velocity in cm per sec; and h is Planck's constant, 6.63×10^{-27} erg-sec.

It is obvious from this equation that speed and wave length are related; the higher the speed the shorter the wave length. This relation between speed and wave length is important in all interactions between neutrons and atomic nuclei since it concerns what we call "cross section." Cross section is a measure of the probability, per unit of flux and per unit of time, that a nuclear reaction will occur.

The speed of a nuclear particle is usually denoted in terms of its energy in electron-volts (ev). Thus a particle with an energy of, say, 0.1 ev, in accordance with the formula given above, will have a wave length of a hundred-millionth of a centimeter (10^{-8}cm). This is approximately the diameter of the average atom. However, the nucleus of the atom is some ten thousand times smaller than the atom itself and this leads to questions concerning the neutrons in the nucleus. In the fission of U^{235}, slow speed neutrons of energies considerably less the 0.1 ev enter the U^{235} nucleus to form a compound nucleus which in a very short interval, fissions and divides into two, not necessarily equal, parts.

The question is, how is it possible for a neutron, with dimensions at least ten thousand times larger than a nucleus, able to enter that nucleus? Very early in the development of nuclear energy it was discovered that neutrons were much more likely to be captured by nuclei if they were first slowed down to very slow speeds (thermal neutrons). This was puzzling at first, but it soon became evident that this behavior was the result of the neutron behaving essentially as a

wave. As the speed of the neutron is reduced, its wave-length becomes longer—it is larger. It is obvious, therefore, that the larger wave has a better chance of hitting nuclei and being absorbed than a small bundle of very short waves. In other words, by slowing down the neutron we increase the effective cross section.

In the interaction between neutrons and nuclei, waves also have a mysterious way of passing through extremely dense nuclei. It is as though these waves, coming in contact with the surface of a nucleus, instantly reproduce themselves on the opposite side with no effect on the nucleus itself. This is one of the strange consequences of wave mechanics—something that is not in our power to visualize but which goes on in the sub-atomic world at all times.

Within the nucleus, neutrons have extremely high energies—energies of around 50 million electron volts. At such energies the wave length of the neutron is extremely small (10^{-13}cm), and in this case the neutron has more of the characteristics of a particle. Hence, because of the very small wave length, many neutrons are able to exist within the nucleus itself.

Structure of the Neutron. One of the amazing accomplishments of nuclear physics is that it has become possible to gain some concept of the structure of the neutron itself. This is possible because of the magnetic properties of the neutron.

Although the neutron is electrically neutral, it is not necessarily magnetically neutral. As is well known, an iron bar becomes a magnet because of the moving electric charges of the electrons of the atoms. When the atoms are aligned in the same direction, the sum total of all the tiny atomic magnets produce the over-all magnetic field of the iron bar. The atoms themselves, however, are electrically neutral.

The magnetic field of the neutron is produced in somewhat the same way. In the case of the neutron, the moving charge is the meson. Mesons are transient particles that arise during energy transformations in atomic nuclei. When nuclei are bombarded by high energy particles, mesons are emitted. These mesons have varying masses depending upon the energy involved in the bombardment, and outside of the nucleus have only a transient existence. They disintegrate into electrons or other products in a millionth of a second or so. Much is still to be learned about meson reactions.

Currently, the neutron is considered to be composed of a proton surrounded by negatively charged mesons. The negative charge of the meson exactly balances the positive charge of the proton; hence, the neutron as a whole is electrically neutral. The meson which circulates around the proton, however, constitutes an electric current and creates a magnet field which makes a tiny magnet of the neutron, with a north pole at one end and a south pole at the other. Because of this magnetic field it is possible to polarize a beam of neutrons, and this enables nuclear physicists to learn more about the structure of the neutron than would otherwise be possible. There is still much to be learned about the way the meson in the neutron, after a relatively short life of ten minutes, is able to turn into an electron and a neutrino. However, when we consider that less than three decades ago the neutron was completely unknown and that very little was known about the structure of the nucleus, it is obvious we have come a long way. With advanced experimental techniques and higher-power particle accelerators now available there is every reason to believe that the next decade will reveal much more about the ultimate nature of matter and energy.

Andrew W. Kramer

How Much Steam Should a Steam Trap Trap?

. . . some answers to commonly asked questions about the primary job of a steam trap

You don't need a doctor's degree in thermodynamics to answer the question at the top of this page. Naturally, a steam trap should trap *all* the steam.

Unfortunately for you, the problem isn't quite that simple. After all, a shut off valve would trap all the steam . . . and condensate, and air, and carbon dioxide as well.

So we'd better amend the answer to the question this way: A steam trap should trap *all* the steam but *must* remove condensate, air and carbon dioxide as rapidly as they accumulate.

With this established, let's take a closer look at what's involved:

A Steam Trap Should Trap All The Steam

If you've had experience with several different makes of traps, you already know that some trap steam better than others. The operating principle of the trap is what makes the difference. We like to talk about it because Armstrong traps are designed so that no steam can get to the orifice. The valve is always water sealed. Result: *More efficient steam utilization, lower fuel costs.*

A Steam Trap Should Remove Condensate

All traps remove condensate—after a fashion. For maximum efficiency in the unit being drained, though, the trick is to get it out without waiting for it to cool and without leaking steam.

Armstrong's water sealed valve takes care of steam leakage. The inverted bucket operating principle opens the trap for water regardless of its temperature. This means you get the condensate out as quickly as it accumulates. Result: *Higher temperatures and better heat transfer in steam heated units.*

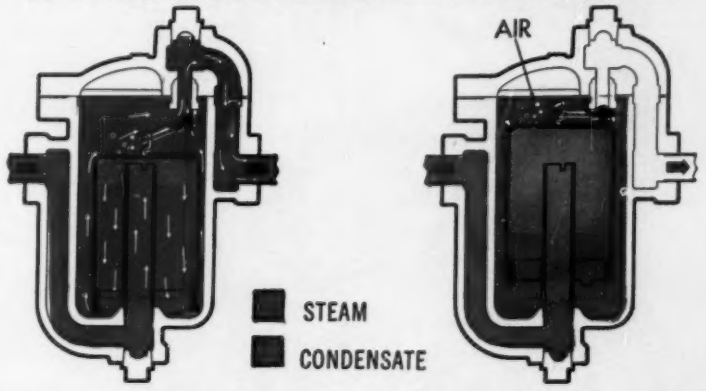
A Steam Trap Should Remove Air and CO_2

Part and parcel of the condensate removal problem is removal of air as well as oxygen and carbon dioxide—two real troublemakers. Air tends to reduce operating temperatures and interfere with heat transfer. CO_2 goes into solution to form corrosive carbonic acid which, for example, can eat unit heater tubes. O_2 aggravates the situation. Believe it or not, but all traps don't properly remove air and CO_2.

By now, you've probably guessed that Armstrong traps *do* remove air and CO_2. Armstrong design (see illustration) provides continuous venting of air and CO_2. By opening suddenly, the Armstrong trap creates a momentary pressure drop to "pump" the air down to be vented. Result: *Higher temperatures, faster heat-up, better heat transfer and reduced corrosion.*

Note: When required, specially sized air vents are furnished. For fast heat-up of low pressure on-and-off units, Armstrong provides open float and thermostatic air vent traps.

HERE'S THE STEAM TRAP DESIGN THAT GETS RID OF CONDENSATE AND AIR WITHOUT STEAM LOSS



Trap open. Condensate entering trap has caused bucket to lose buoyancy. Weight of bucket times leverage pulls valve open. Air is discharged along with condensate.

Trap closed. Steam has floated inverted bucket; valve is held tightly closed by system pressure. Air entering trap passes through bucket vent and accumulates at top of trap.

What's the Final Answer?

Summing it all up, you'll get the best service from steam heated units that are equipped with traps designed to trap *all* the steam and remove air and condensate as quickly as it accumulates. In our prejudiced viewpoint, this means Armstrong traps. More important are the several thousand users of Armstrong traps who have proved the point.

Before you make up your mind, though, consider the minimum maintenance requirements of Armstrong traps . . . and the convenient assistance your local Armstrong Representative provides. These are important plus values.

Put Up or Shut Up

We're so confident that we "put up". Armstrong traps are unconditionally guaranteed to satisfy. So you can find out for yourself with practically no risk. If you're not completely satisfied with the way they do their job, you can get your money back.

* * *

The 44-page Armstrong Steam Trap book goes into greater detail on these and other Armstrong features. It also discusses trap selection, installation and maintenance. Ask your Armstrong Representative for a copy or write

Armstrong Machine Works
8104 Maple Street
Three Rivers, Michigan

ARMSTRONG STEAM TRAPS

See our catalog in Sweet's Plant Engineering File

For more data circle 538 on Post Card

from the . . .

"HORSE and BUGGY" DAYS

• Shown at left is one of the first portable boilers. This was a horse drawn combination boiler and steam engine built in sizes from 6 to 20 horsepower and popular during the 1860's.

from the Dobbin Drawn Portable .

• As you can see, Erie City Iron Works has been in the boiler business a long, long time. Before the turn of the century we were building portable boilers similar to the horse drawn unit above. Simple in operation and rugged in construction, this type boiler gave many years of dependable service particularly in oil field and sawmill work.

Today we build a complete line of firetube and watertube package steam generators from 1,700 lbs./hr. to the 100,000 lbs./hr. unit shown at the right. This Keystone is a complete, modern package with burners and controls piped and wired prior to shipment. This **natural circulation** boiler is symmetrical in design with double steel encased insulated side walls. No baffles, handholes or key caps are required on this unit. Maximum heating surface coupled with conservative ratings produce low exit temperatures and highest efficiencies.

Investigate the possibilities of renovating an antiquated, costly power plant with Erie City Keystone Steam Generators — modern as a Jet, rugged in construction and simple to operate. Write for bulletin **SB-5902-A.**

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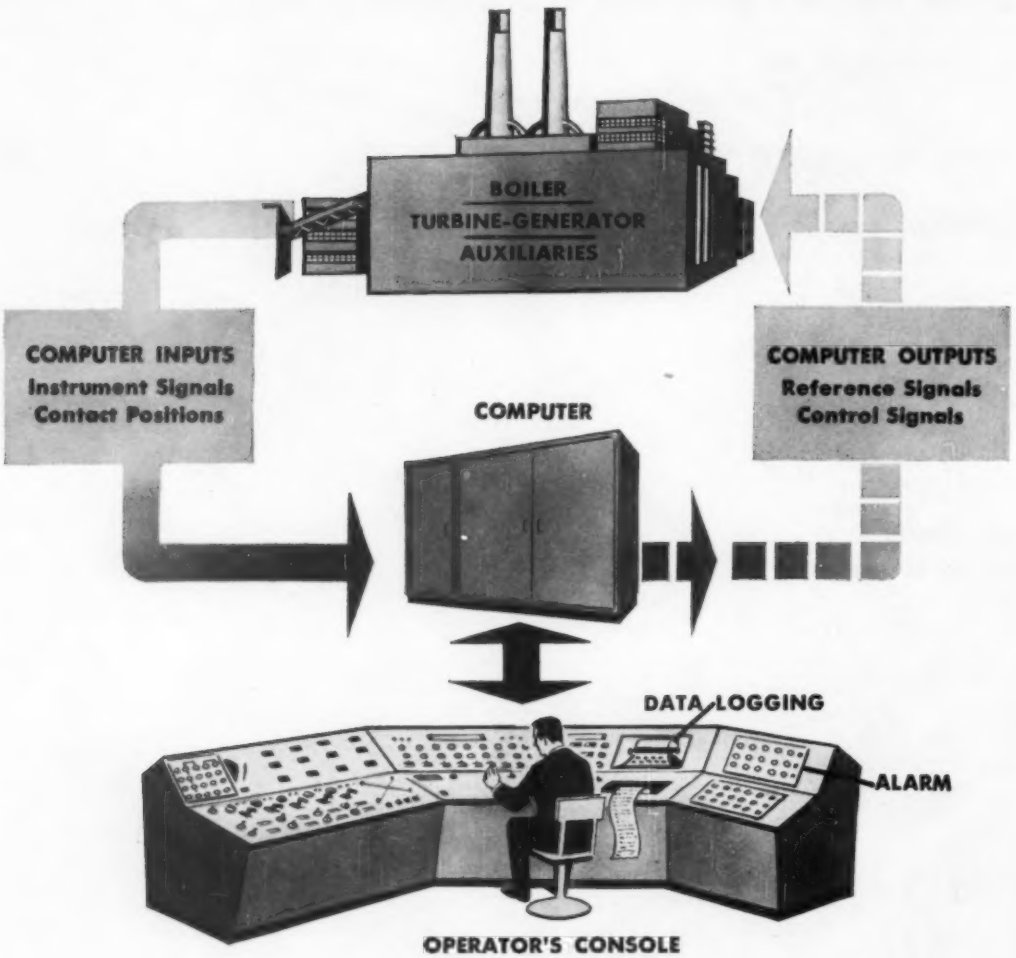
General Electric reports to the electric utility

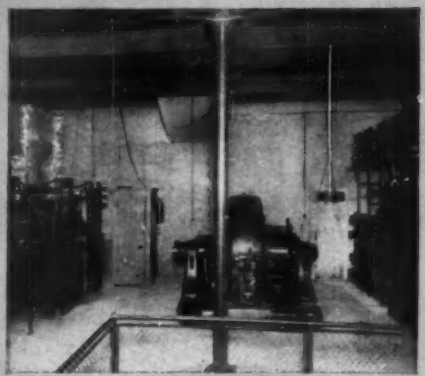


GENERAL ELECTRIC'S DEPTH OF EXPERIENCE IN SYSTEM DESIGN

General Electric's competence in power plant automation extends well beyond its ability to design and manufacture many of the complex components of the system.

81 YEARS OF EXPERIENCE in the utility field has given General Electric distinctive skills in integrating many and varied types of equipment into reliable and smoothly operating *systems*.

AUTOMATION DEVELOPMENTS pioneered by General Electric, in co-operation with its utility customers, cover all parts of the utility system, from generation through relaying to metering. A partial listing of such developments over the years would range from the automation of hydroelectric generating stations more than 40 years ago to the development, a few years ago, of automatic load dispatching systems.



FIRST AUTOMATIC SUBSTATION, at the Union Station of the Elgin and Belvidere Electric Company, was developed by General Electric in 1914.

industry on progress in . . .

POWER PLANT AUTOMATION

AN ENGINEERING REALITY today, the automatic power plant was a dream until recent developments in solid-state digital computers supplied the missing element: a reliable "brain" compatible with already existing sensory devices and automatic sub-loops.

GENERAL ELECTRIC'S COMPUTER CONTROL SYSTEM now makes possible completely automatic hot and cold starting, on-line corrective action, normal and emergency shutdown, and continuous control of the boiler-turbine-generator-plant auxiliaries system.

BENEFITS TO BE EXPECTED from this advanced computer control system include reduced outages due to careful preplanning of programmed action to minimize undesirable operating conditions and human errors. Improved fuel economy should also result from the availability of continuous information on plant and component efficiencies, and from the allocation of load schedules in accordance with actual (instead of historical) operating conditions.

GENERAL ELECTRIC'S ENGINEERING COMPETENCE in the field of electric utility automation began early and has influenced all parts of generation, transmission, and distribution systems. This competence is solidly founded on the long-standing familiarity of General Electric engineers with basic phenomena in the generation, transmission, and distribution of electricity.

SEVERAL DEGREES OF POWER PLANT AUTOMATION are available to you now. General Electric will work directly with you or with your consulting engineer to design and co-ordinate anything from an improved and automatic data acquisition system to complete automation of your power plant.

For more information on this dramatic new development, write to the General Electric Co., Section 301-411A, Schenectady 5, N. Y.

Progress Is Our Most Important Product

GENERAL ELECTRIC

FIRST AUTOMATIC POWER PLANT, a hydroelectric plant, was installed at Cedar Rapids in 1917. It was developed by General Electric.

FIRST SYSTEMS PLANNING AID was offered to electric utilities over 40 years ago by General Electric. A-C network analyzers (above) have been used since 1929.

FIRST APPLICATION OF COMPUTERS to automating the design of heavy electrical apparatus was pioneered by General Electric. Computers help solve once unsolvable problems.

THE HAGAN CONCEPT OF THE AUTOMATIC PLANT

The concept of an automatic power generating station is receiving thoughtful consideration in today's world of power. Profit-conscious managements, aware of the attendant risks in the headlong approach to total automation, are closely examining the hardware available today—from a standpoint of performance, experience and reliability. They are asking searching questions about their process and its performance equations—questions that must be answered before managements can determine just how far and how fast they will proceed toward the goal of a fully automated plant.

Considerations on which the Hagan Concept is based are: *payout, usage and investment.* Eventual payout must be carefully balanced against cost, since even an optimum control-computing system compromises such factors as reliability and simplicity, accuracy and sensitivity. While a "push-button" plant is feasible, the number of times the button will be pushed during the life of the unit must be considered when weighing the capital investment in equipment. And since computer capacity will stand idle until all the control loops and associated hardware are proved in action, and operators gain the necessary experience, the timing on the purchase of the computer is important.

There is a plan of action that lies between the headlong approach, with its attendant risks, and the less costly but non-productive wait-and-see viewpoint. This compromise approach is the Hagan Concept—which provides for a *logical* succession of steps towards the automatic plant, with each step a complete function.

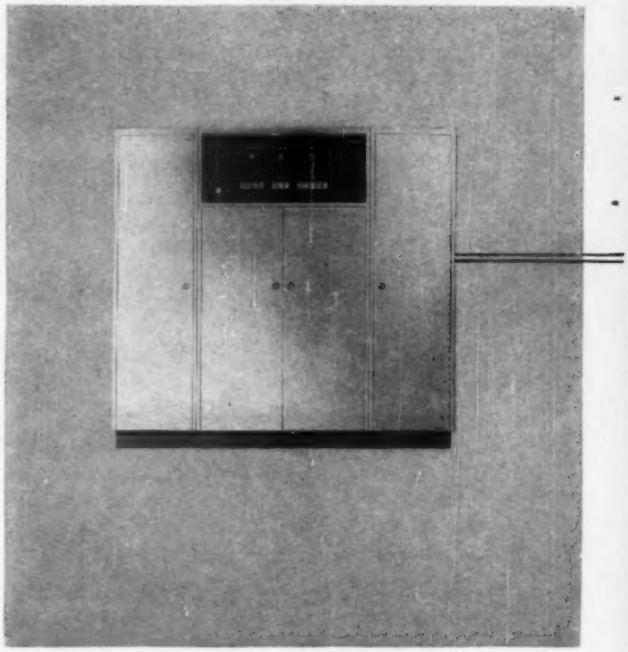
Step One: Install an analog (solid-state) electronic control system. This will take advantage of the proved reliability of analog-type control elements for actual plant operation, and will provide a workable foundation for proceeding to the next step. Maximum reliability is provided by an electronic control system utilizing magnetic amplifiers. Economy is achieved by utilizing compact remote control stations that hold panel space to a minimum.

Step Two: Install a scanning-logging system (solid-state). This can be done simultaneously with Step One. Obviously the data system must be compatible with the control system to gain economy of installation and operation.

The final steps toward complete automation—"computing facilities," "utilizing available processed data," "optimalization of the analog control loops," and "complete programming for automatic start-up and shut-down"—should be taken after start-up and commercial operation of the plant is accomplished. Anticipated 99% reliability of computer facilities is not good enough for continuous commercial operation. When based on actual plant operating experience, and when all final actuating devices have been proved reliable, programming for automatic start-up and shut-down can proceed intelligently and soundly.

We will be glad to send you a more complete exposition of the Hagan Concept. Write or phone Hagan Chemicals & Controls, Inc., Hagan Building, Pittsburgh 30, Penna. Phone: WAlnut 2-3737.

HAGAN SOLID-STATE



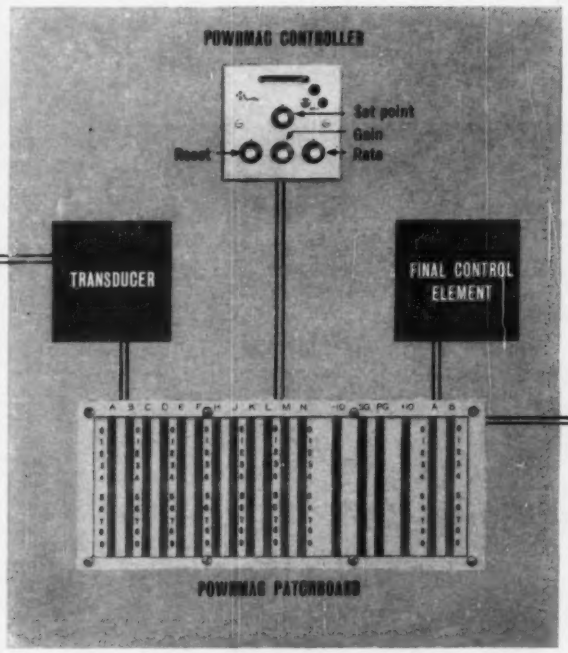
SERIES 2000 KYBERNETES DATA SYSTEM

Completely compatible with the PowrMag Line, the Kybernetes Data Processing System encompasses all the necessary functions to perform logging, calculating and alarm scanning operations. Standard design includes linearization, square root extraction, AC to DC conversion, multiplication, division and digital alarm comparison. Kybernetes 2000 will handle inputs from thermocouples, AC and DC transducers and digital inputs. Input switching is handled by a relay matrix, so arranged that the failure of any input relay cannot invalidate the entire device.

Complete random access to *any* variable is immediately available. The system is completely isolated from induced voltages and from ground currents. A patented, all-electronic self-balancing DC amplifier provides elimination of noise, yet has excellent frequency response. Designed for maximum utilization, the Kybernetes system provides great flexibility. By utilizing parallel inputs, amplifiers and storage devices, it is possible to perform the functions of totalization and computation *without interrupting the normal logging, alarm scanning and visual display functions.*

Pinboard programming on a pre-wired board permits easy selection of the desired operational characteristics, such as: full-scale ranging, trend logging, alarm set points, or function programming of such items as linearization, square root extraction, computations or number of digits to be logged.

CONTROL AND DATA PROCESSING

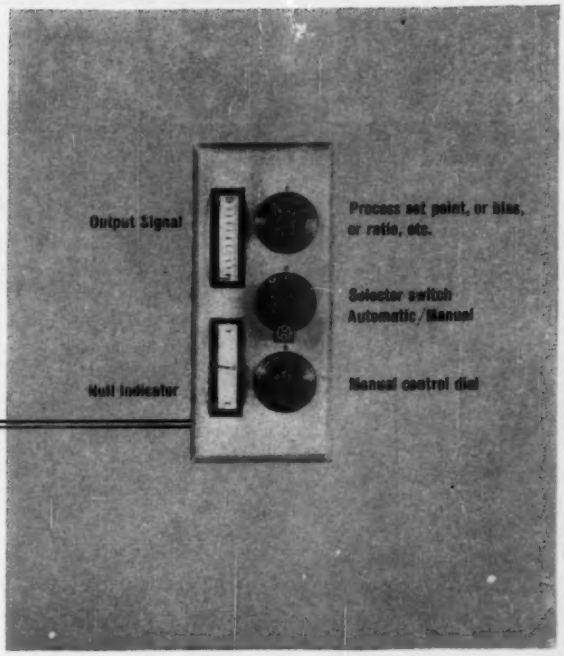


HAGAN POWRMAG CONTROL SYSTEM

A solid-state, Analog Computer Control consisting of four basic elements, PowrMag (magnetic amplifier) combines reliability with extremely low maintenance. A typical system would include:

1. Input Transducers for converting variables into 1-9v DC electrical signals.
2. Analog Control Computer consisting of operational magnetic amplifiers, which, in association with plug-in passive network components, perform all computing functions, including addition, subtraction, division, integration and differentiation.
3. Remote Control Stations to provide for remotely established set points as well as required manual control operations.
4. Final Control Elements, such as electro-pneumatic or electro-hydraulic operators.

Hagan PowrMag control systems are extremely flexible, easy to install, and foolproof. All components plug in and are completely interchangeable. Interconnections are made at a central patchboard by means of taper pins. Requiring a special tool for insertion or removal, the taper pins are foolproof and tamper-proof. Each connection is identified on the patchboard by an alphanumerical combination. Changes in the system are readily accomplished, and more components or loops can be added easily.



REMOTE CONTROL STATION

Easy to operate, cleanly designed, the station requires no operator memory. Front mounting and removal make it ideal for use in compact console installations. Whole station is 2¼" x 5¼"; half station is 2¼" x 3⅛".

Each station uses 12-wire color-coded electric cable with M-S type connector. Full station may contain two single or ganged potentiometers, one switch and two meters. Half stations provide set point, bias or ratio dial plus output signal indicator.

Today PowrMag and Kybernetes equipment is being built or is at work for a wide variety of industries. PowrMag installations include complete boiler, metallurgical furnace, glass furnace and glass fiber die control systems. Kybernetes installations are performing such functions as data logging, processing and calculating as well as temperature monitoring in refineries, power plants, municipal water works and chemical plants. A letter or phone call will put Hagan experience to work on your problem.

Write for PowrMag Bulletin MSP-163 or Kybernetes Bulletin MSP-161.

HAGAN
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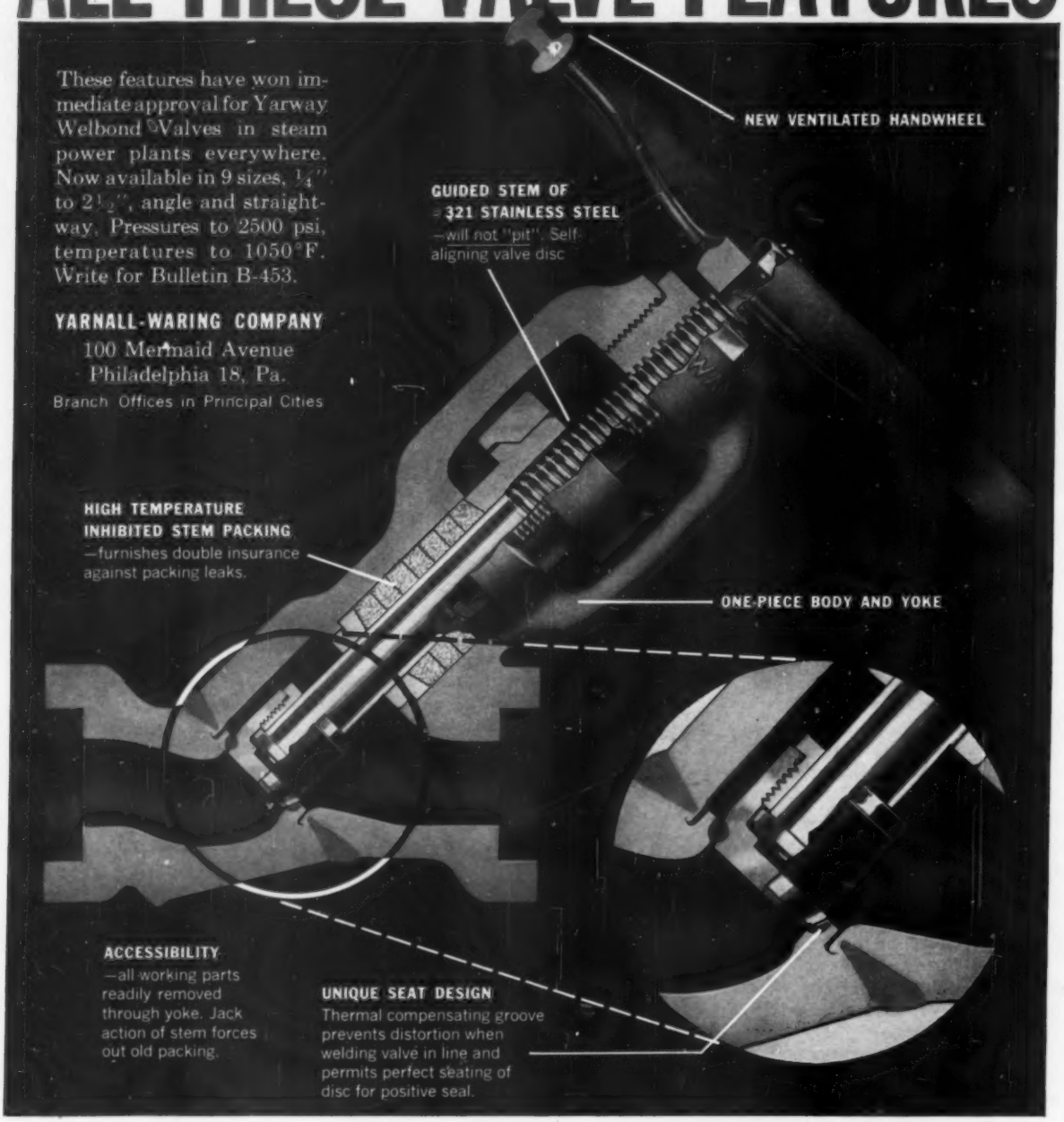
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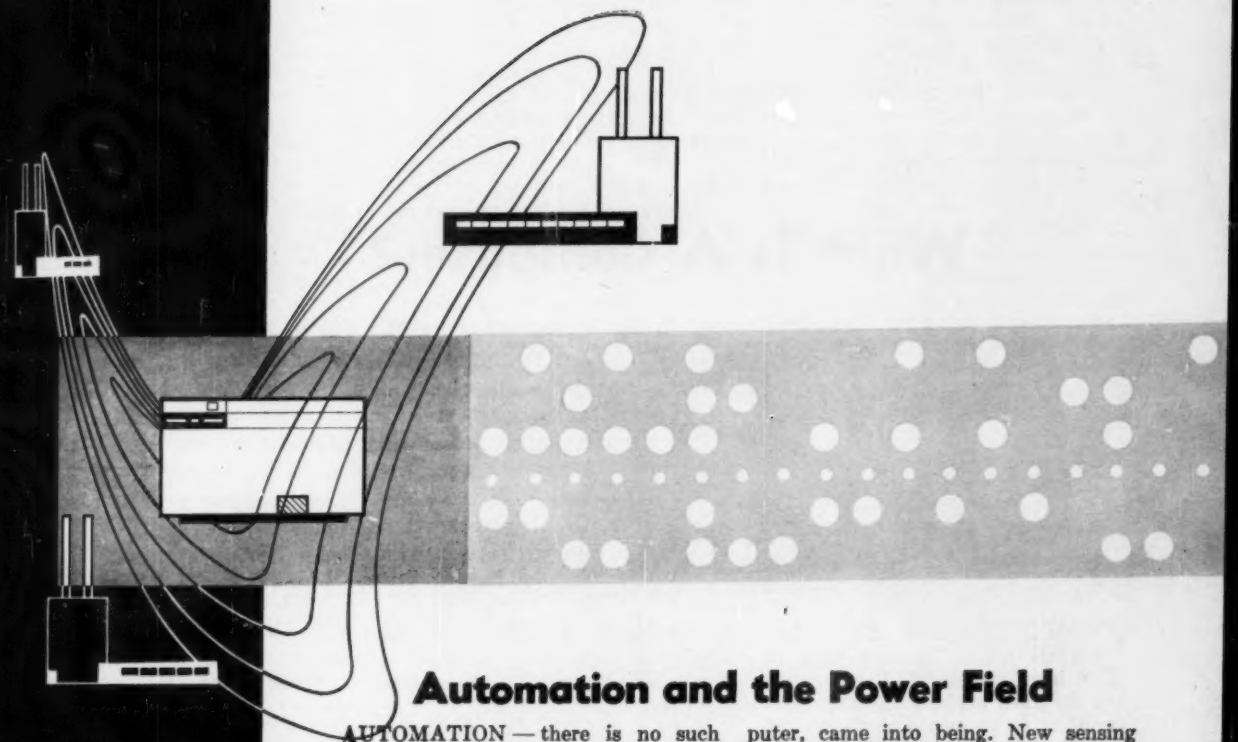

To keep you abreast of constantly changing vistas in the ever-dynamic field of POWER ENGINEERING we present the first of a new series: CHANGING SHAPES IN THE WORLD OF POWER

EDITED BY

JEFF HUNNICUTT
ASSOCIATE EDITOR

Automation and the Power Field

AUTOMATION — there is no such word, says Webster. But its principles are well known. James Watt laid the first cobblestone in the roadway to automation of the power engineering field in 1788 with his steam engine governor. From that day forward, the march to the automatic power plant has been relentless and undeviating.

Early in the Twentieth Century, the first integrated combustion control system was sold and installed on the premise that it would result in fuel savings in the order of ½ per cent. That such systems, subsequently refined, went far beyond savings of that meagre order is history. Two- and three-element feedwater control systems appeared on the scene with equally gratifying results.

That these systems depended heavily on meticulous preliminary testing and, in many cases, specially-shaped cams to fit each application was not of primary concern. That they were effective only when treating with standard conditions was not of major significance.

Present decade saw development of the trend to ever-larger generating units with higher and higher conditions of steam pressure and temperature. With them were introduced a whole new set of controls problems that served to accent and magnify the above-named shortcomings. Clearly, a new advance in generating station control was needed.

Coincident with this demand, new and dramatically different control mediums became available. Seed sown earlier in military applications came to fruition. Entire new concepts of control technology, centered about the electronic computer, came into being. New sensing devices, accurate far beyond the dreams of James Watt or Charles Smoot or E. G. Bailey, were developed.

Today, two new generating units with radically different control systems have come off the drawing boards into the construction phase, each vying with the other for prestige that will accrue to the world's first completely automatic push-button plant. Countless others are in the preliminary study stage, and already are overshadowed by more recent thinking, looking beyond the generating unit and the automatic plant to the automatic system with any number of so-called push-button stations under direction of a system master computer. It is as inevitable as tomorrow's sun.

Doubtless, this first generation of automatic stations will suffer by comparison when that day arrives. Much more important, however, is that a start has been made: A very substantial start that can culminate only in the completely automatic generating system.

That there is widespread and emphatic disagreement on how best to arrive at this goal should come as no surprise. Unresolved problems are many, as are those with favored theories and methods of attack.

Automation is truly the most challenging and forceful changing shape in the world of power today. To help you meet that challenge, we present here the thinking of what we consider to be twelve foremost authorities in the field. If they at times disagree emphatically, the goal is common: Automation of the dynamic field of power engineering.

CHANGING SHAPES . . .

What Is A Computer?

By TAK YAMASHITA

Mr. Yamashita is an engineering graduate of the University of Colorado. After 4½ years of military service as a guided missile officer assigned to research and development, he became associated with the Computational Laboratory of the Guided Missile Development Division of Redstone Arsenal. Since 1955 he has served as the Manager of Applications for the Bendix Computer Division

COMPUTERS ARE NOT electronic brains, as they have so often been publicized. Rather, they are the most modern scientific tools enabling us to obtain mathematical and logical results at the speed of electricity.

Computers are categorized generally as digital or analog. An analog computer is one in which numbers, for purposes of computation, are converted into physical quantities such as lengths or voltages. Precision of results obtained with this device depend upon precision of fabrication and skill of operation. A slide rule is an example of an analog-type computer.

Digital computer is a device which performs mathematical operations with numbers expressed in the form of digits which can assume only discrete values. Results obtained are expressed in digits, and precision of the computer depends upon the number of digits it is designed to handle. An example of a digital computer is a desk calculator.

Many analog and digital computers of varied sizes, speed of operation, and cost are available. Moreover, many different types are used for specific purposes. These are referred to as special purpose or one-time machines. These special purpose computers will be discussed later.

Discussion here will be around high-speed electronic digital computing equipment. Desk calculators are generally used to perform arithmetic operation; that is, to add, subtract, multiply and divide. A keyboard is used for input, and the device is manually controlled. Automatic digital computers differ from calculators in that they are of electronic design and capable of solving complete significant problems, quite beyond mere arithmetic operations, without human intervention.

Speed of operation and general usefulness make an automatic digital computer equivalent to thousands of calculators and their attendant operators. In addition, the modern computer has the ability to transfer, modify arithmetic operations, and make decisions in thousandths or millionths of a second, which makes it practical for use in solving problems otherwise unsolvable.

Digital computers usually consist of racks of electronic circuitry containing many tubes or transistors, a storage device, and other basic electronic components. The equipment is usually organized into five major units as shown in Fig. 1: storage unit, arithmetic unit, control unit, input unit and output unit.

Storage unit. Solution of any complex problem requires that steps to

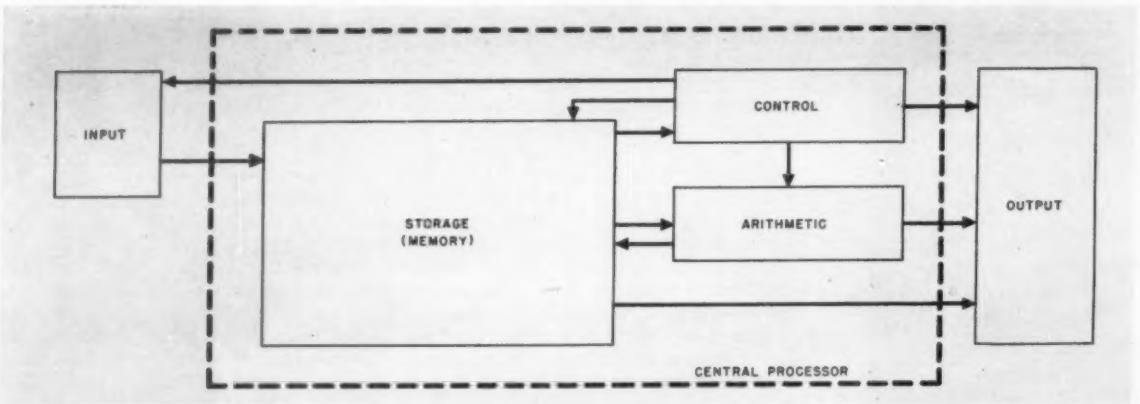

Fig. 1. Block diagram shows how major units described in text are usually arranged to form computer-control installation

solve the problem are "memorized." Storage unit is used to memorize a sequence of instructions or commands and numerical data to perform steps of the required computation. Storage units are available in many forms. Today's computers usually employ a magnetic drum, magnetic cores, or magnetic discs.

Storage unit is divided into many individual units called locations or cells, each of which is capable of storing either a number or an instruction. Each location is specified by a number called the *address*. The content of a storage location is commonly referred to as a *word*. Thus, the capacity of storage units, for example, are referred to as two thousand words, twenty thousand words or thirty-two thousand words. Length of the word or "word size" is expressed by the number of decimal digits a storage location can hold.

Arithmetic unit. Need for this unit is self-evident, since arithmetic computation is a prerequisite to the solution of a mathematical problem. This portion of the hardware is used for arithmetic and logical operations.

Control unit. Function of this unit is to direct the sequence of operation, interpretation of each instruction, and to send proper electrical signals to the arithmetic unit and other parts of the computer in accordance with its interpretation.

Input unit. Sequence of instructions and data are read into the storage unit of a computer by the input unit. This unit is usually a keyboard or "reader" with the ability to read information on punched paper tape, punched cards, magnetic tape, and the like at extremely high speeds.

Output unit. When a problem is solved, the final answers are transmitted electrically to an output unit. This unit is a device that can record computer output as a curve, or as a set of printed results. These units are usually in a form permitting results to be displayed at a relatively high rate of speed.

Arithmetic, storage and control units are usually combined "hardware" and are referred to as the central processor.

One of the important concepts of an automatic digital computer is its ability to perform, based on a sequence of instructions or commands.

Standard terminology used in the preparation of the commands is referred to as *programming* or *coding*. The words programming and coding are used synonymously, since programming means to plan careful records and to draw a flow chart or block diagram of the steps in which a problem should be solved.

Associated with each digital computer is a set of operation codes (machine instructions) that are used in coding the problems. The storage unit, as described, is divided into locations, and each location is specified by a number called the address. These are usually referred to numerically, and in sequential order. By use of these basic principles, a mathematical problem is solved. Figure 2 shows the steps in a portion of a program for the calculation of

$$\frac{a^2 - bc}{d}$$

where a, b, c and d are stored at addresses 1100, 1102, 1104 and 1106 respectively.

Operation code and address as written is then prepared on a document (punched tape, cards and the like) depending on the facilities of the input unit. The computer is instructed, manually or automatically, to solve the problem. Control unit of the computer will then read each instruction in sequence, performing the necessary operations specified.

Results obtained are then printed, as instructed, by the output unit. There are many varied coding systems; however, the general philosophy and approaches used are the same.

A general purpose machine is designed for use in solving problems which are likely to be extracted from a reasonably broad field of application. A special purpose digital computer is a machine designed to serve a very narrow field of application.

Auxiliary equipment to electronic computers are pieces of equipment to perform analog to digital conversion as well as digital back to analog for control purposes. Function of this equipment is to provide an electronic means by which computers can be connected directly to measuring instruments and control devices.

A large percentage of all actuators and control devices operate on pneumatic or hydraulic signals, whereas the computer can accept only electrical signals. These conversion devices are therefore designed to accept these pneumatic or hydraulic signals, convert them to electrical signals of corresponding value, and to feed these signals to the computer for analysis and appropriate action. The control signal then comes from the output unit of the computer in the form of another electrical signal of specific value, and this, in turn, is converted to a pneumatic or hydraulic signal of corresponding value acceptable to the device doing the controlling.

Manner in which computers and conversion devices are used depends largely on application of the system and the operation desired. Combination of these computers and conversion devices are modern tools which open the door to new and advanced techniques in the field of power generation as well as all process industry.

To solve $\frac{a^2 - bc}{d}$ where a, b, c and d are stored at addresses 1100, 1102, 1104 and 1106 respectively, these steps are performed:

	Command Location	Operation Code	Address
1. Clear accumulator and add b	0900	42	1102
2. Multiply b, in accumulator, by c	0901	44	1104
3. Store bc	0902	49	1108
4. Clear accumulator and add a	0903	42	1100
5. Multiply a, in accumulator, by a	0904	44	2100
6. Subtract bc from a^2	0905	41	1108
7. Divide $a^2 - bc$, in accumulator, by d	0906	48	1106
8. Print contents of accumulator (results)	0907	33	2100

Fig. 2. This tabulation shows sequentially the steps a computer would take in solving a typical mathematical control problem

What Control Computers Can—and Cannot—Do

CHANGING SHAPES . . .

By HENRY L. BECHARD

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WITH THE ADVENT of reliable components, use of digital computers as an adjunct to complex process control systems is now being accepted as a useful tool. Digital computer's ability rapidly and accurately to process data and do complex computations with that data allows plant management to operate the process much closer to optimum.

However, use of a computer to assist the operator in running a plant will not yield perfect operation. First of all, the computer acts only as a supervisory tool that is programmed to handle normal plant fluctuations and changes in operating conditions.

Operator must be ready to take over control in unusual circumstances and, indeed, must be aware of all actions taken by the computer.

Secondly, measuring and control devices feeding data to and accepting signals from the computer are not perfect, and mathematical formulation of the control problem can only be as accurate as current human knowledge of the process. For these reasons, the computer should be regarded as a new kind of control instrument, capable of producing improvements in plant operation sufficient to warrant management's investment.

Digital control computer, like ordinary electronic digital computers, is composed of a network of electronic switching circuits and a digital memory device. These are so arranged that they can perform a set of arithmetic and logical operations in a sequence specified by a program of instructions recorded in the memory device.

Instruction code of the computer contains arithmetic and logical operations appropriate to efficient handling of control problems. The control problem which the digital control computer computes is determined by a program of instructions recorded in the memory device. This program can be changed by changing the recording, with no changes in the equipment.

Unlike conventional computers, the digital control computer is directly connected to measuring and controlling instruments through signal converters. Data that the control computer requires in order to perform its control functions is immediately introduced into the memory from either punched cards or paper tape, without need for manual data recording and translation.

The digital control computer can also accept data entered either by typewriter keyboard or by punched paper tape or cards in order to allow the operator to enter data not immediately accessible to the computer. Such data may be related to management decisions, equipment switchover in the plant, and a variety of other information not readily sensed by conventional instrumentation.

Wherever feasible, however, converters are used to convert measuring instrument signals into electronic signals the computer can use, and to convert computer signals into a form that can directly control other instruments.

Digital control system can be thought of as an operator who follows a very complicated set of instructions which direct him to make many arithmetic calculations, to "read" many instruments, and to adjust many intermediate variables automatically, continuously, and without error. The system has facilities which make it possible to connect temperature, flow, level, and other measuring instruments directly to the computer so that it can immediately determine which adjustment should be made so as to operate in the most efficient manner within a given set of equipment limit specifications.

Computer is also connected directly to the equipment which adjusts the intermediate variables, so the computer can take action directly. It may also notify the operator when it has determined that some modification is necessary or desirable. A typewriter input-output or *logging* system is provided to enable it to communicate with a human operator.

In addition to keeping the process running at optimum conditions, the computer may have a number of other useful functions: it can be used to interpret instrument readings and to calibrate instruments periodically; it can be used during start-up and shutdown to insure that operations are carried out in a predetermined sequence; it can be continually and tirelessly on the lookout for instrument and equipment failure; and it can collect and interpret performance data for later study by engineering and research staffs.

In order to achieve real-time optimization, the computer is linked directly to controller set points and repositions these set points to maintain automatically optimum conditions. Accepting inputs concerning operation as well as information on factors such as required production rates, it continuously monitors operation to insure that all variables

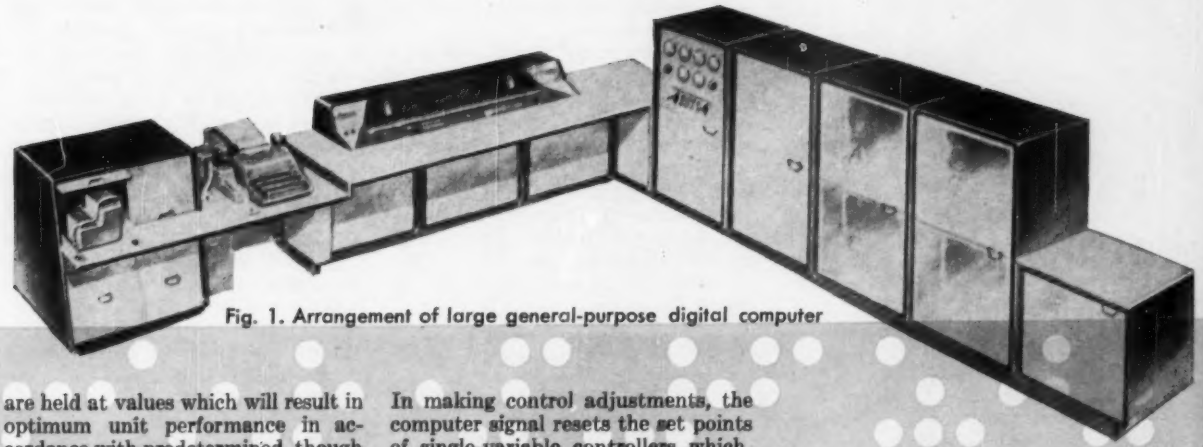

Fig. 1. Arrangement of large general-purpose digital computer

are held at values which will result in optimum unit performance in accordance with predetermined, though possibly varying, criteria based on input data and equations in the memory.

The digital control computer is only an adjunct to the entire process control system. It acts as a supervisory device that is capable of making rapid and accurate complex calculations that an operator could not, or would not, have time to make. It does these functions on-line and in real-time, and in this way the tremendous data-processing abilities of the digital computer are available to help the operator in controlling the process.

Further, since the computer fulfills its functions by adjusting analog controller set points and by alerting the operator as to the control actions it is directing, computer failure will not cause plant shutdown. Judgment of the human operator will still be available, supplemented by data provided by the computer, and he will still be capable of taking over control.

Digital control systems for real-time applications require a substantially higher degree of reliability than that required for engineering computations or business data processing. Operating time percentages of 85 to 95 per cent, which are actual operating norms for most commercial data-processing equipment, are not at all adequate for real-time control.

Control computer must be able to run continuously for weeks without failure if it is to be useful and economical. To be acceptable at all, such a system must be fail-safe. Such systems can be designed.

One of the most effective safeguards in an automatic system is the manner in which the computer makes control adjustments. In systems designed today, the computer is not connected directly to devices that make control adjustments. Most such variables are maintained at given settings by single-loop controllers. In making control adjustments, the computer signal resets the set points of single-variable controllers which, in turn, make correction in the variables.

Thus, in event of a failure in the computer, the process is maintained at the last setting or, in more sophisticated systems, gradually returned to a known safe state. Availability of operators to override during unusual conditions (including, perhaps, computer maintenance time) makes this system feasible from the standpoint of reliability of existing hardware.

Effect of random computer errors can be minimized in a number of ways. The computer can be prevented from taking drastic control action on the basis of faulty computations by being restricted to making adjustments in modest increments and monitoring effects of the adjustments. Another part of any computer program is a detailed self-checking routine which exercises and checks all arithmetic and logic functions of the system and notifies the operator of any malfunction.

Another important area in which a computer can contribute greatly to over-all system reliability is that of detecting instrument failures. A digital control computer might be 100 per cent perfect itself, but if normal instrumentation failures could lead the computer blindly into an upset, the entire system might be considered worthless. It is the responsibility of the program to guard tirelessly and constantly against this situation.

To monitor controllers it can check set-point deviations, looking for a discrepancy between the measured value of a variable and the desired value which it has calculated and sent out to the controller. For instrument transmitters or signal pick-ups, it can watch for false full-scale readings beyond the physical range of the data and, by comparing present values with previous ones, it can detect instruments which have stuck or which are varying too rapidly.

For an analytical instrument where the computer supervises periodic checks against a standard, the program may watch for excessive drift in the instrument's calibration. At a more sophisticated level, it may check interrelationships of a group of variables, such as total steam flow from, and condensate and make-up feedwater to a boiler.

Several installations have now been made or are being planned for the power industry. In these instal-

Fig. 2. One of many types of signal converters for process computer control

lations, a digital control computer will perform the following functions:

1. Log any desired number of variables at intervals of a few minutes on output typewriters. In addition, the operator may manually instruct the computer at any time to print out the absolute values of one or more independently selected variables, to print out all variables, or to print out all set-points. In this manner, an operator may follow trends on individual variables during periods of system upset.

2. Scan and alarm any desired number of variables or computed points. In addition to conventional alarm scanning, a general purpose computer-logger has the ability to change automatically a limit point as a function of some other variable, or to remember both good and bad past performance, and act accordingly.

3. Control plant operations by means of analog and digital output signals. Analog signals may be used to reset the set point of electronic controllers and/or pneumatic controllers by means of suitable transduction equipment. Digital signals may be used to set and reset switches and to perform other logical decision-type actions.

Functionally, these actions may be combined with memory-stored production costs, line losses and the like, plus continuous input data supplied by control instruments to perform the following specific operating requirements:

1. Calculate and automatically control the most economical allocation of generating capacity. Computer can do this by simulating unit fuel costs, turbine and boiler characteristics, transmission system losses, and composite station heat rates.

2. Upon command of the operator, automatically start the plant equipment from a hot or cold condition, continuously checking during the start and stop that prescribed initial conditions have been met. During both these operations the operator is continuously informed of actions taken by the computer, and of any dangerous conditions that may arise.

3. Continuously monitor plant operating conditions.

4. Automatically signal and correct abnormal conditions.

5. Maintain the plant at optimum efficiency by adjusting equipment as necessary to follow system load demands, while taking into account any uncontrolled variables such as circulating-water temperature, fuel analysis, equipment fouling, atmospheric conditions, and the like.

All of the above features are of direct use to operators and to management, and fulfill functions that are at present being done, at least in part, by manual operation.

A computer system may cost as little as $150,000 if it is used strictly as a computer-logger. It may cost as high as $300,000 if the complex control functions are included. Actual cost depends upon the number of computer inputs and outputs, number and type of new instruments required, amount of process modification necessary to make effective use of the computer, and the amount of project engineering required to plan and install a system.

Typically, a system for the power industry that would control plant operations and perform automatic start-up and shutdown might cost as follows:

Computer	$100,000
Input-output equipment	70,000
New instruments	20,000
Process modifications	50,000
Engineering	50,000
Total	$290,000

As with any plant modification or improvement program, justification for expenditure of money must be found.

It is obvious that the computer can at once do as well as human operators do now by merely connecting the input and output devices to the computer and programming it to duplicate human operating decisions. However, the computer can make much more rapid decisions and much more complex calculations than can a human operator. In addition, it can adjust controller set points much more accurately.

Justification for the computer system can usually be found by taking advantage of these factors to supply the following benefits:

1. Plant will operate in a much more stable or uniform condition, eliminating minor upsets that can occur hourly or more often. In the power industry, this will lead to a reduction in fuel costs.

2. More accurate and convenient records will be kept. These records will make it easier to control the process, will provide records for accounting purposes, and will provide data for systematic analysis.

3. There will be significant maintenance savings. By means of linear programming, the computer can schedule maintenance on various units at economical optimum time.

4. There will be fewer outages and accidents. Computer can anticipate and avoid instabilities or hazardous conditions which can cause the operation to be shut down for repairs.

5. There could be a reduction in plant personnel. By continuously monitoring plant conditions and operation, a computer could allow the use of one less operator.

In addition to the potential direct savings, use of the computer system in minimizing major accident risks should also be carefully considered. On the average today, a major accident for a 200-megawatt unit would cost about $1,000,000 in damage and from two to four months' outage time. Minimizing such risks by using automatic monitoring equipment is extremely valuable to the user, even though it is not a direct cost justification.

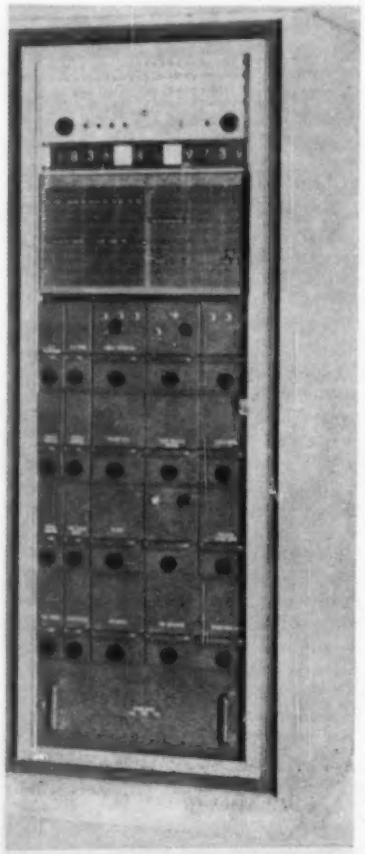

Fig. 3. Another A–D conversion device

Transition: The Memory of Machines For the Initiative of Man

By TSAI HWA LEE

Mr. Lee is Manager of Applications Engineering for Process Computers, Computer Div of General Electric Co. Before joining G E in 1957, he served as Procedures Analyst and Systems Engineer for Detroit Edison Co, and as Director of Detroit UNIVAC Computing Service Center for Sperry-Rand. He has co-authored a new book, "Programming Business Computers", published by Wiley & Sons

WEBSTER defines a program as a "plan for future procedures." As long as human endeavor existed in civilized society, programming, or the preparation of a program of one sort or another, was in use.

In the early days, as the nomad moved from one oasis to another, there was a program of planned activity for each and every camel and member of the household. Later on, as society became more complex, written procedures, or plans of action, gradually replaced some of the individual initiative. This insured uniformity of action and some continuity of performance, regardless of individuality. Thus, the burden of programming shifted from the individual to written procedures, and recently to machines, and more specifically, to computers.

In the office, in research, and in the production plants, the human initiative is being replaced partially by the computer with its great speed. It is the repetitive type of initiative that will be replaced, while sophisiticated initiative, as used in the preparation of programs, will become a part of the computer.

This article summarizes the transition of the various stages of programming, and discusses in some detail the concepts of programming a computer, how a stored-program computer works, some considerations of programming, and new methods that reduce programming costs.

In the early days, when individual home workshops constituted a business entity, individual initiative and thinking was the sum total of programming. In other words, as each situation or problem arose, the individual thought through the appropriate plans or procedures of action. This approach had immense flexibility because the worker could use a great variety of ways to solve the same problem. On the other hand, the disadvantage was the lack of standardization and uniformity. The worker may have had to re-invent the wheel with each problem.

As the one-man shop grew into an organized approach involving dozens or thousands of people, it was no longer feasible to use the programming approach, letting each man think out a solution when confronted with a problem. A means had to be found to systematize the practices in the workshop, the accounting function, and the distribution of goods in an organized fashion. This was necessitated further by the standardization of goods and services required by mass production.

Solution that met the requirement at that time was an approach that used written systems, procedures, standards, and practices. No longer was the individual allowed to reinvent the wheel or let his mood prevail in the factory or office over standard items. This would have led to chaos and gross confusion. Programming thus consisted of setting down in writing the best ideas of pro-

Fig. 1. General Electric's GE-312 Process Control Computer in typical arrangement

duction engineers and systems and procedures analysts, and then finding a means of properly supervising, measuring, and quality-controlling the execution of these plans.

As business grew in size and complexity, the second stage of programming by the written word gave way to mechanized programming. Small control and calculating devices came into the picture to reduce the drudgery and the flood of paper work involved in setting up the program and measuring the results. Specific examples are small punch card calculators, desk calculators, individual recorder-controllers, and others.

Thinking that goes into the planning of these programs is much more sophisticated, because of the more complex devices used and necessary reduction in flexibility due to mechanization. During the execution of the program, the man still is very much in the picture. The operator is required to adjust the set points of controllers and to exercise judgment in case of abnormal operation.

Age of automation brought about a much higher degree of sophistication in programming than ever before, through the use of computers. Instead of relying on the man to operate the various pieces of calculators, to adjust and trim individual controllers, and to exercise judgment in case of abnormal operation, the computer is now utilized to remember the previously thought-out plan of action. Thus, programming consists of analyzing the problem, then thinking-through the solution ahead of time, putting these plans into the computer.

Stored-program computer came into being about 1947, and to date there are over 2000 stored-program computers in use. In this type of computer, the program is stored in the memory of the computer. The memory can be extremely large, say several million items of information. Thus a single computer can be used for very large applications.

Stored-program computer also allows a program to modify itself, and it allows the storage of many alternative functions, selected according to its decision-making ability. This permits the stored-program computer to be used as a self-optimizing or self-adaptive device where the program can be changed automatically.

The stored-program computer usually consists of such components as the memory, the control section, the arithmetic, and the input-output sections.

Memory contains the program, the data, the tables, and the constants. The memory is also used as the general working storage area.

Arithmetic section can be considered as an electronic desk calculator, performing at electronic speeds such functions as addition, subtraction, multiplication, division, and decision-making operations.

Control section interprets each instruction to determine what should be done, brings the proper operand from memory into arithmetic section, performs the arithmetic operations, and fetches the next instruction.

These functions are sequentially and automatically performed at electronic speeds. It is possible to perform thousands, or millions, of computations in a second, through the use of the electronic control section that automatically sequences the course of the program execution, without human intervention.

Input-output section, as its name implies, brings in numbers, analog voltages, and visual indications.

Stored-program computer may be used to log, supervise, and control a process. Thus it can digest and reduce data from a process into more compact and meaningful form. The computer will produce valuable performance calculations, providing timely indications of efficiencies and operating guides by which the operator can use his judgment to operate the process. It is also possible for the stored-program computer to have direct supervision and control.

Computer with large memory capacity can operate a process in a more optimum fashion because of its ability to perform very involved and sophisticated computations. Where the operator can usually see one or two variables, the computer can take into account a much larger number of factors and variables, perform intricate calculations, and direct commands to the variables that will operate the process.

Computer also can store, in its memory, a carefully thought-out program of setting up or starting up a process, *e.g.*, the boiler-turbine-generator process. This insures that the best thinking of the planning, operating, construction engineers, and the equipment manufacturers are incorporated into the start-up procedure. With the information in memory, such a procedure will be faithfully followed time after time. The computer will assure maximum safety to the equipment because many more crucial points can be scanned more rapidly.

Tremendous speed capability of the stored-program computer allows to be done many more things which the individual operator cannot do. Its large memory allows more sophisticated methods and techniques to be implemented. Thus we see the stored-program computer taking its place not only in the office and the research lab but also in the factory, production facilities, and steam-power plants.

Programming, in a broad sense, includes defining the problem, performing the analytical and mathematical work involved, devising a scheme of using the computer to solve the problem in the form of flow charts, and converting the solution outlined by the flow charts into computer language, that is, coding. Final stages of programming include the program checkout and preparation of operating reports. Many special techniques peculiar to programming have been developed in the last 10 years. These include numerical analysis, use of sub-routines, and use of non-machine language programming.

Perhaps the most critical phase of programming is the problem-definition phase. Emphasis here is computer-oriented problem definition. A new way of thinking is needed, besides knowledge of the steam plant, its instrumentation, thermodynamics, and controls. This new way of thinking involves what a computer is, and what it can and cannot do.

On the positive side, a more intimate knowledge of what computers can do will help the engineer to plan a control system far superior to that which he is accustomed. With experience, he will soon find the computer is a friend with some natural limitations which he has to get used to, but in the long run his new friend can produce many benefits for him.

As the problem is defined, the first step in converting the solution of the problem into computer language is *flow-charting*. In contrast to other types of charts, such as organization charts, this type of chart is a dynamic one which flows, hence the name flow-charting.

Flow chart consists of boxes to indicate things to do, and arrows connecting these boxes, indicating what to do next. Thus the flow charts spell-out to the computer the sequence of operations it must go through to solve the problem. Flow chart can also conveniently indicate the logical decision involved in the solution of the problem. For example, if the value

of a quantity is within the high and low limits, no action is taken and the computer is directed to scan the next point. On the other hand, if either the high or low limit is exceeded, the computer may be directed by the program to produce a visual or audio alarm, and the point in question is printed out. Thus, flow-charting is analagous to the outline of an essay, and *coding* is the writing of the essay.

Coding is the solution of the problem in computer language. Computer language usually recognizes an operation code and operand address for each instruction. Since the computer executes one instruction at a time, preparing the code consists of writing down line after line of instruction to implement the solution in the flow chart. Coding also involves keeping accurate account of where each word of the memory is utilized and what information is being stored.

In general, programming and coding is a tedious and costly task if done entirely by manual means, but the use of sub-routines and non-machine language coding techniques have greatly eased the burden of coding. Sub-routines are groups of instructions for frequently used functions, organized into such a form that they can be used over and over again by different people, to solve different problems, without repeating the drudgery of turning out these lines of coding again.

Thus, we have sub-routines for the calculation of sine, cosine, and for the various performance calculations of the turbine-generator. Non-machine language coding allows the coding to be done in a language more convenient to the programmer and closer to the language of the problem. This type of coding lets the computer itself convert and assemble the coding written in this simplified language into the computer language.

For example, even though the GE-312 is a binary computer, the coding is actually done using mnemic alphabetic operation code and decimal addresses. It is estimated that techniques, such as the use of sub-routines and non-machine language coding, have effected savings in programming in the order of at least five to one.

Computer is a new tool to implement the general trend of automated programming: an automatic means to implement sophisticated human initiative. Man's initiative and ingenuity will not be overruled by the computer, but the computer makes it possible for these to become realities. Computer will store man's initiative and make it available at electronic speeds to make decisions resulting in safe, reliable, and optimum operation.

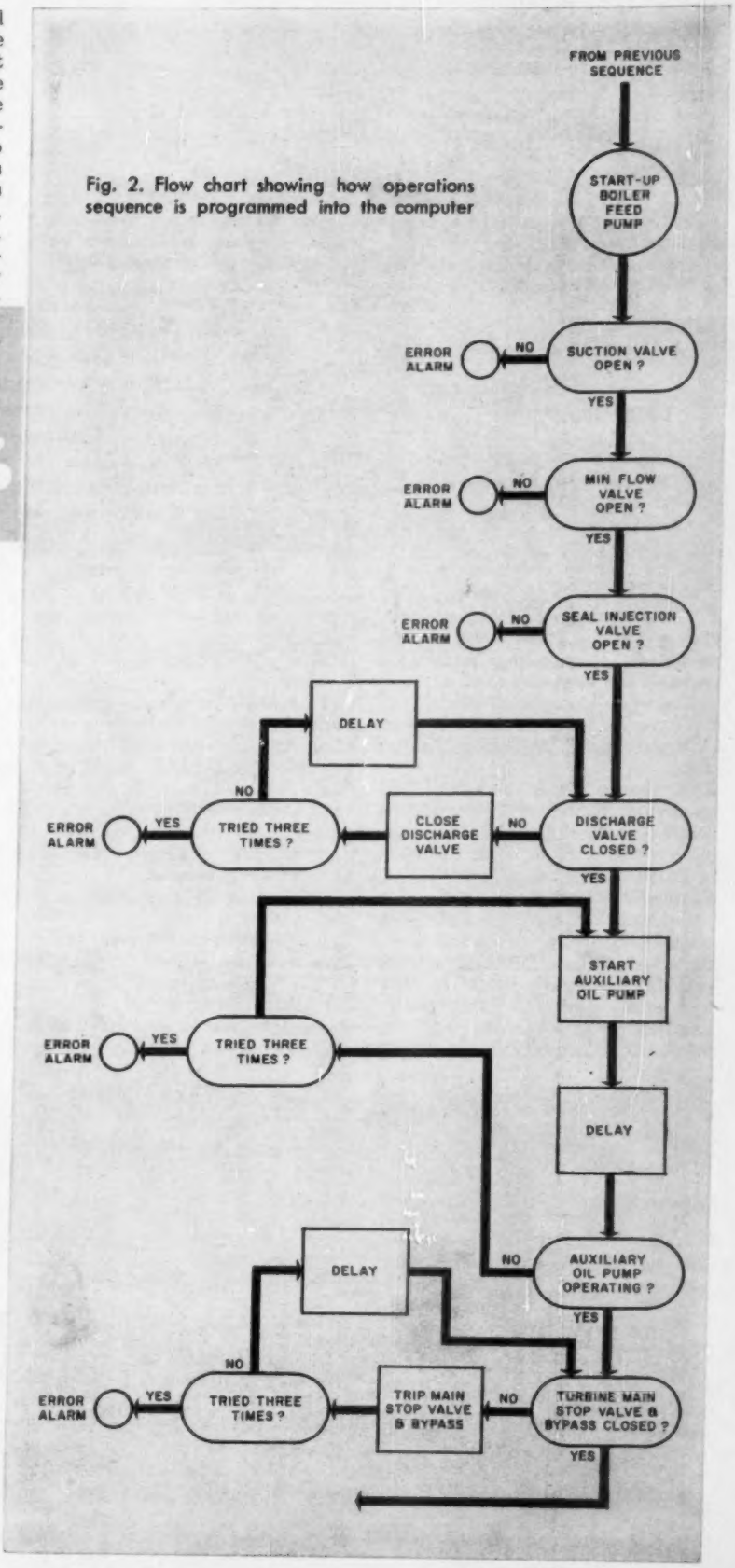

Fig. 2. Flow chart showing how operations sequence is programmed into the computer

Supervisory Control and Scanning:

. . . the foundation

By THOMAS M. NOURSE

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FOUNDATIONS on which complete automation of a steam generating unit stand must be sound. To be sound the foundations must meet practical and economic facts of life:

1. Start-up date must be met.
2. Human operator confidence must be maintained in the early installations.
3. Equipment installed must have maximum reliability. This must be based on proved experience and not on conjecture as to what the ideal ultimate system will require.
4. In the formative stages, compact presentation of more than the conventional operating guides will be required. Operating variables must be reliably and automatically scanned and monitored and intelligently grouped for human monitoring.
5. Computer capacity should be flexible, and it should be possible to manipulate the computer without interrupting the basic control loops or the reliable presentation of data to the operator.

To achieve completely automatic optimal control of a steam generating unit and still meet the aforementioned facts of life based on today's technology and economics, these logical steps, therefore, are suggested:

1. Install an electronic solid-state analog control system.
2. Install a solid-state scanning and logging data system.
3. Install computer capacity to compute from process data.
4. Use computed data to optimize the analog control loops.
5. Add programming capacity for automatic start-up and shutdown.

These steps may be taken one at a time with the next one taken after the preceding one is field-tested, or the complete package is available today. However, the time to achieve final successful operation of such a complete system will be the same whether purchased in steps or purchased at the same time, since the same extensive field testing and proving of associated hardware will prevail in either case.

Once the computer is separated from the analog control loops and the processing of field data for presentation to the computer, it (the computer) can be treated for what it really is: a flexible program device that readily can handle clean input data and return clean, accurate output information for performance monitoring, optimization, or programmed start-

Fig. 1. Readout and control panels like this provide operators with greatly improved control data on instantaneous basis

up and shutdown of the unit to be controlled.

While Step No. 1 in the above listed logical steps may seem obvious to many, it cannot be overlooked. One has only to tour this country, visit stations, and talk to the human operators to realize the large number of installed analog control systems that are not truly automatic.

Steam temperature control that will not handle load swings; combustion control that will handle load swings but falls apart on fan failure or pulverizer trip-out; steam temperature control that relies on the fine touch of a human operator for successful control during periods of attemperation; systems requiring gain changes or ratio changes to cover entire control range: all are examples of poor dynamic response capability of too many present day systems.

We will not achieve completely automatic computer optimized control until we achieve individual control loops that are truly automatic and can operate unattended. If not, it would be necessary to store programs to meet every possible contingency such as pulverizer trip-out, feeders plugging, fan trip-out, and the like.

While any amount of stored program information is perhaps possible, the better approach will be to build on sound foundations. The first of these is a truly automatic analog control system.

Second necessary foundation, and the one that is the first step in the advancement toward the automatic plant, is the supervisory control and scanning equipment. Fundamental requirements for this equipment include:

1. Maximum reliability approaching the reliability of the analog controls. This will be achieved through use of fewest possible and most reliable components. Faults must be self-identified as nearly as possible and must cause minimum down time.
2. Ability to handle wide range of plant data easily and cleanly and with complete freedom in the choice of transducers as to a-c, d-c or digital types.
3. Memory of ranges, high and low alarms which are constant when the unit is on the line, thermocouple linearization, and simple calculations protected against loss of memory in case of any type of power failure or malfunction of internal system programming.
4. Flexibility and easy expandability as to number of points or exchange of points.
5. Compatibility with additional digital computing and programming capacity. However the data system programming, ranging, alarming linearization, and simple calculations and other fixed programs should not use up the capacity of a digital computer with flexible programming. If a data system is truly to replace recorders and other alarm scanning devices, it must be reliable and should not be integrated with the understandably lower reliability of a digital computer.
6. Data system should be able to scan, monitor and alarm, but *scanning must continue* regardless of the read-out mode selected such as "on demand log," "trend log," "manual select digital display," "automatic sequential digital display," and "trend sequential digital display" — or when alarm conditions exist.
7. System must have provision for fast scan (less than 10 seconds) and slow scan (approximately one minute depending on the number of points).

Function of the data system as a sensor or monitor of plant conditions must serve two functions:

1. It must be a reliable replacement for other recording and indicating devices and must compactly and logically present more data to the operator.
2. It must process all required plant data for inputs to a computer.

For the logical presentation of information to the operator or to a computer, plant data should be categorized as follows:

1. Variables or contact closures requiring instantaneous annunciation or alarm.
2. Variables requiring approximately 10 seconds monitoring or alarm.
3. Variables requiring approximately one minute monitoring or alarm.

The above are all in the category

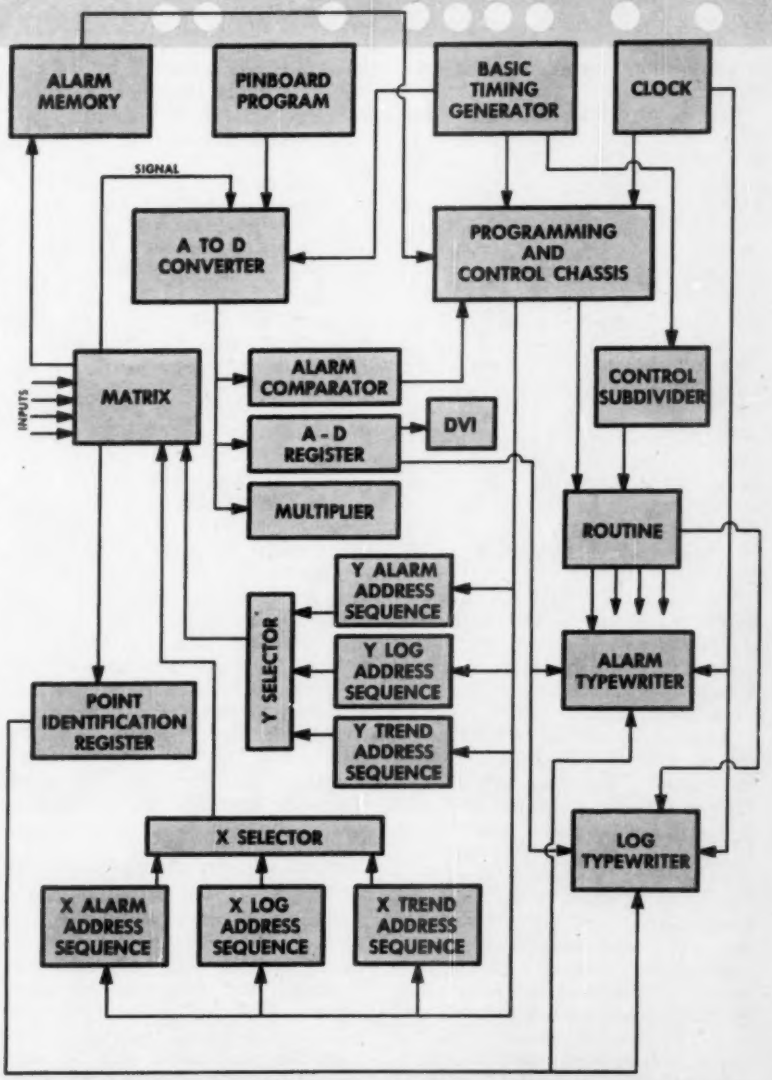


Fig. 2. System block diagram shows scan and alarm circuits in over-all system

of operating data. Plant variables and results should also be separated further into performance data and historical data. However, with the exception of contact closures, all the above classifications require conversion from raw analog data to clean digital form through the data-processing system.

In this article we will deal in detail only with the presentation of operating data to alert operating personnel to undesirable deviations from normal conditions.

Alerting for off-normal can be done with annunciators with audible alarm, data system console light display with audible alarm, and off-normal print-out on the typewriter or other read-out device with audible alarm. In a well-considered design, each of the above mediums will be used.

Not considering inputs required for automatic programming, as this is not in the scope of this paper, a typical unit in the 200- to 500-megawatt range will have approximately 400 to 450 inputs required for operating, performance, and historical data. Of these, approximately 250 are in the category of operating information or more specifically in the category requiring audible and visual alarm to the operator for off-normal conditions.

Studies indicate that of these 250, approximately 40 require instantaneous annunciation or alarm and segregation from the other points to designate the seriousness of the off-normal condition.

Another 75 will have instantaneous alarm since they are simply contact closures, but these can be separately and more compactly displayed and can have a separate audio signal. Of the remaining points, approximately 30 will require 10-second-or-less scanning speed with visual and audio alarms and off-normal print-out. The remaining 105 can be scanned at a rate of approximately once a minute and will have visual and audio alarm and off-normal print-out. The last 135 points referred to above will require conversion from raw analog data to digital form in the data system. The 105 points that can be slow scanned will be combined with the other 150 to 200 points, which are being digitized for logging, visual display, computer input or a combination of all three.

The 40 points which require immediate alarm would be displayed on a conventional annunciator which would identify the point both in words and in data point number. The operator would have available to him on the main operating console a digital read-out panel as shown in Fig. 1. Above the read-out panel would be a bank of identifying lights, which would also be engraved to identify the point in words and data point number.

Read-out panel would give the operator the ability to select manually any point for visual display, regardless of modes being carried out by the basic data system, such as periodic log, etc. To do this, the data system must be designed to continue scanning, regardless of the mode selected by the operator.

Thus, in actual operation, when an off-normal alarm is sounded, the audio tone would identify the point to be on either the annunciator or the read-out panel. Lighted annunciator panel or read-out panel light would identify the point as to function and data point, as mentioned above, and the operator could immediately select the point for visual display on the digital indicator shown in Fig. 1. He then can observe trend of that point as long as he keeps it on manual select. Again it is paramount that both fast and slow scanning continue while he is looking at the selected point.

With this facility the operator will, in much more orderly and compact fashion, actually have more information readily available to him than previously. This will be necessary to keep personal confidence in his ability to operate safely a 200- to 500-megawatt unit from a 5 to 10 foot console. If processed data is not readily available, confidence will be lost. Certainly if processed data is not reliably maintained, confidence will be lost.

Data system to satisfy the above discussed uses should be designed around the following general philosophies and specifications:

To approach a reliability factor of 99.9%, which will be required of a fully-utilized data system as described above, the system must be constructed in such a manner to facilitate fast and simple maintenance. Modular construction and self-identifying fault features must be used to accomplish this. System should be built up from a minimum number of basic sub-chases to minimize spare part stocking problem.

Inputs must be electrical in nature. They can be a-c or d-c; and 0 to 10 millivolt minimum and 0 to 1 volt maximum control scale signals should be handled directly.

Input switching must be highly reliable and provide for random access to allow the aforementioned requirement of alarm scanning to continue during logging, trend logging, or manual selection of a point. A relay matrix composed of hermetically sealed relays for each input point provides this type of flexible input selection. Failure of a single relay does not invalidate the entire input device. The faulty relay can be easily and quickly identified and replaced without causing complete system failure.

Isolation from stray ground loop currents must be provided. This can be accomplished by sequential chopping of the input on to a condenser, and hence from the condenser into the data system. In this manner the data system never is actually connected to the field input, thus isolating the input from the system.

D-c amplification must have high frequency response, high noise rejection (1000 to 1), high-input impedance (10 megohms), and a long-term drift of less than 30 microvolts.

A-c to d-c conversion should be capable of producing a d-c voltage proportional to the peak voltage of the a-c signal to an accuracy of 0.05 per cent full scale.

Analog to digital conversion must be accurate to 0.1 per cent or 1 digit in 1000. System should be capable of making at least 50 analog-to-digital conversions per second so as to allow time-sharing of this section for integration, division, multiplication, etc. Sweep voltage versus time and binary weighing techniques are the most commonly used methods.

Alarm comparison is best performed digitally so as to provide accuracy to one digit. Fixed alarm points should be stored in an absolutely non-volatile memory system, such as a pin board.

Linearization of thermocouples is also best performed in the basic data system with its absolute non-volatile memory. With the sweep voltage technique of analog-to-digital conversion, linearization is easily accomplished to an accuracy of one degree or less depending only on the accuracy desired.

Foundation discussed herein, which is the supervisory control and scanning, must meet the above discussed practical operating considerations and design considerations. To meet this challenge will require experience, desire, and intelligently designed and applied equipment.

Sophisticated Logging and Station Analysis: The Next Logical Step

By ALBERT F. SPERRY

Mr. Sperry is President of both Panellit, Inc, and Information Systems, Inc. Formerly he was Vice-President of Republic Flow Meters Co and President of Hubbard Engineering Co. He was the first National President of Instrument Society of America. He is an Honorary Member of ISA and a Fellow of ASME. He is a Registered Professional Engineer and holds many patents in the fields of instrumentation and control

DIGITAL COMPUTER, the "brain of the modern data processing system," is a powerful but complicated instrument. Unless applied with considerable sophistication and care, it will never realize its full potential in the control of power generating stations.

On the other hand, its capabilities are impressive. For those who are willing to devote the time and effort required for its intelligent application, rewards will go beyond the more obvious savings from fuel and labor cost reductions. For those, however, who expect it to provide a short cut to plant automatic control, frustrating delays and disappointments may be in store.

There is a logical sequence to the steps toward complete automation of a power station. This sequence embraces an *information phase*, Table I-Phase A, which can be made operational today. For the second or *automatic control phase*, Table I-Phase B, however, information and computing techniques are ready, but the simple fact is that the equipment is not.

Sheer volume of engineering and design effort needed to prepare the generating equipment for automatic start, stop, and control is such that considerable time must elapse before it can be studied, evaluated, and built into safe, reliable control gear.

It is possible today, in the next logical step, to install a data processing system with sufficient sophistication, not only to make all the steps of Phase A operational, but to open the way for a systematic and orderly attack on Phase B.

This step-by-step approach is not only the most likely to justify itself economically, but it is also the fastest and surest road to complete automatic station control.

This discussion will deal with the "hardware" problems involved in applying digital computer techniques to the program of Phase A in Table I. It will touch only lightly on the equipment problems of Phase B, since these are discussed more fully in other articles in this issue.

Information Content. On-line process computer requires better input signals than the single-channel analog controller, simply because it uses the signals to do more things and generally tries to squeeze more information out of them. At the same time it presents new problems, because a single measuring device is switched to many different inputs and must be matched to a broad range of signals.

Inputs. Special practices in wiring and installation are needed to avoid errors from magnetic pick-up or unbalanced ground potentials, particularly if the signals are at low level (below 50 mv). These include proper shielding, careful grounding, and a very high regard for isolation of the measurement circuitry and power supplies. Balancing of lines and filtering of individual input lines are sometimes necessary, but they must be applied judiciously since they present dynamic problems of their own. Recent developments in low-level differential amplifiers make it possible to measure thermocouple and strain gage signals at fairly high scanning speeds, but they do not eliminate these errors.

Computations and scaling should be made after the analog signals are converted to digital numbers. A typi-

Table I. Logical sequence of steps to complete automation of power station

PHASE A. CONTROL FROM INFORMATION

1. Monitoring Plant Operation
2. Refining Information Content
3. Performance Calculations
4. Comparison With Predicted Results
5. Programming-Dispatching

PHASE B. AUTOMATIC CONTROL

1. Automatic Sequencing of Accessories (fans, pumps, etc.)
2. Combustion and Feedwater Efficiency
3. Automatic Turbine Start-Stop
4. Automatic Boiler Start-Stop
5. System Control (Both Feedback and Programming)

Table II. Memory pattern for power system with 400 inputs. Note two different word lengths: 19 bits for machine instructions, 13 bits for data constant storage

	Words	Bit per Word	Approximate Total Bits
A. Machine Instructions	1700	19	32,000
B. Data Constants (7 per input)	2800	13	36,500
C. Output Buffers (2 per input)	800	13	10,500
D. Computation Instructions	4000	19	76,000
E. Miscellaneous, B-Lines, etc.	——	—	5,000
Totals	9300		160,000

cal computation for Total Btu Gas Flow, which might be repeated several times is as follows:

$$H \text{ (in Btu)} = K \times \text{Btu per lb} \times \sqrt{\Delta P \times P \times 1/T \times 1/G \times 1/Z}$$

Such a computation would not only be difficult to perform accurately without a digital computer, but each such computation would require a considerable amount of analog equipment. Actually, several such computations by analog methods might well require equipment more costly than the typical digital computer.

Calibration data for important transducers can be stored readily in the computer memory, and can make possible accuracies that are often impossible or expensive to build into most measuring devices.

Complex functions of the measured signal, rather than the scaled value, often are needed for control or for operating guidance. Thus, rate of change of a temperature, or its average value, may be a much more significant control criterion than its absolute value.

Noise, or extraneous random signals, can be reduced by rechecking routines and correlation techniques, which discard false signals.

Memory. On-line computers are usually more effective when they are equipped with generous amounts of quick-access memory. Usual techniques, in which slower auxiliary devices as magnetic tapes are used as backup memory, tend to slow or even stop the computer when used on on-line programs. Furthermore, ability to modify the data stored in the memory, without stopping or slowing down the program, is essential if a machine is to be utilized simultaneously for analytical as well as on-line operation.

To get an idea of the amount of memory needed in typical installations, a memory pattern for a typical power system having approximately 400 inputs is shown in Table II.

Note that there are two different word-lengths shown: 19 bits for machine instructions and computation instructions, and 13 bits for data constants and information storage.

The ISI-609 system by Panellit, on which this table is based, provides two separate address systems: one for instructions, which addresses two 19-bit words per machine word; another for data constants, which addresses three 13-bit words per machine word. The 13-bit word provides an accuracy of one part in over 8000, which is adequate for any data constants, in real systems.

Figure 3 is a block diagram showing a typical calculation for Gross Turbine Heat Rate in Btu per kwh for a large reheat turbine. Twenty scanned signals are shown as inputs. Two of these are manually set; the balance are analog measurements.

Each double circle represents a rather complex enthalpy computation, and the nine such calculations shown represent the bulk of the computation required.

The small circles represent computed heat contents and heat rates that are stored away and can be read out if desired or, more important, can be used later for more extensive computations on other performance parameters.

Entire calculation uses about 700 words, including instructions and data constants, and takes about 3.0 seconds. Bulk of the time and space are used up by the nine enthalpy calculations. An example of one of these is the enthalpy calculation shown immediately under Fig. 3, which takes up almost 300 words of memory and requires almost 0.5 second per computation.

Number of rather complex computations are involved in over-all station performance, such as 1. Boiler Efficiency; 2. Feedwater Cycle; 3. Condenser and Cooling Tower Performance; 4. Turbine Heat Rates, and the like.

Total memory capacity required to store the program for all these computations is approximately 3000 words. In those cases where it is not essential to perform all these computations regularly, considerable space can be saved by storing those programs that are used only occasionally on paper tape, and feeding them in through paper-tape readers only when needed.

An alternate method of supplying auxiliary memory in large amounts used effectively in the ISI-609 machine is a simple magnetic film which provides up to 130,000 forty-bit words on a single thousand-foot reel.

Speed. Need for speed in on-line computing becomes quite apparent when one considers the complexity of the operations outlined in Table I, which the machine may be called upon to perform. Speed is a capability that must be built into the machine in the first place, since it cannot be expanded, as can memory.

Plant Monitoring. Scanning speed of five points per second seems to be

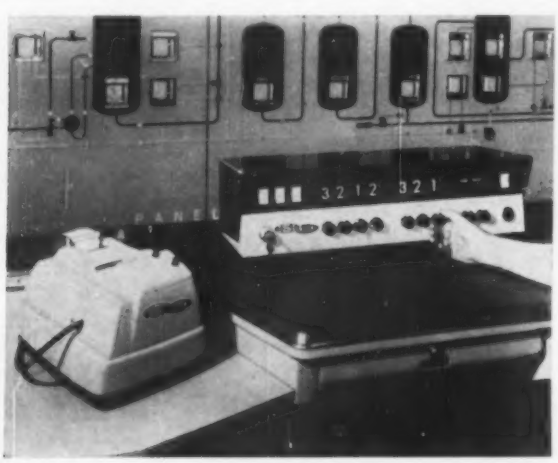


Fig. 1. Operator's Console. Here he can read out values or data constants, can change any control points as desired

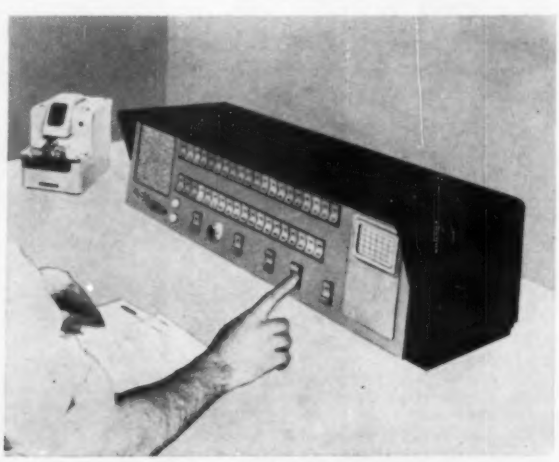


Fig. 2. Computer Console. Here programmer can assume control feed in new program, do independent calculations

a basic minimum for plant monitoring. This gives a sampling rate of one reading per minute for a typical system with 300 inputs, or one minute per scan cycle, which is usually adequate.

Repetitive Computations. On-line information processing often involves simple computations that may be repeated so often that they prove a time bottleneck. Thus flow inputs, requiring scaling and square-rooting before integrating, can use up machine time fast. Programmed square-rooting, for example, can take over 100 word times or more. On-line machines, therefore, should have special one-word commands that can complete a multiplication or square root in a few milliseconds at most.

Analog-to-digital measurement and conversion also fall into this class, and should require a negligible program time, since they are repeated several times per second.

A "time-sharing" technique is now available, which takes advantage of the fact that, at scanning rates of about 5 points per second, the computer itself is actually idle most of the time. It is applicable only to rather sophisticated machines with high speed analog-to-digital conversion, and high-speed scaling, multiplication, and square-rooting.

Systems such as Panellit's ISI-609 make time-sharing possible by providing two distinct channels for information: Channel 1 for on-line monitoring and computing, and Channel 2 for off-line computing or for program modification.

Normal monitoring operations are completed usually in about 25 milliseconds or less, after which the program automatically switches from Channel 2 to Channel 1, where it remains for the balance of the 200 milliseconds. During this time the machine is available for use: 1. as an independent off-line computer; 2. as an on-line computer for computations too long to be performed within the 200 millisecond period; 3. as an off-line computer, operating in the on-line data stored in the memory; and 4. as a program modifier to change the on-line program or data constants when required

All of these operating modes can take place without interfering with the program in Channel 2 for on-line monitoring, or control. Figures 1 and 2 show how these two channels are independently controlled from two separate and functionally distinct consoles. Figure 1 shows the Operator's Console, at which the plant operator can read out visually, or on a strip printer, any on-line values or data constants. He can change data constants, one point at a time, using plain English decimal switches, although a lock is provided to limit changes to authorized personnel. He can print out a summary of all abnormalities, high or low limits, scaling factors and the like at will. He cannot, however, change any instructions or basic programs from this console.

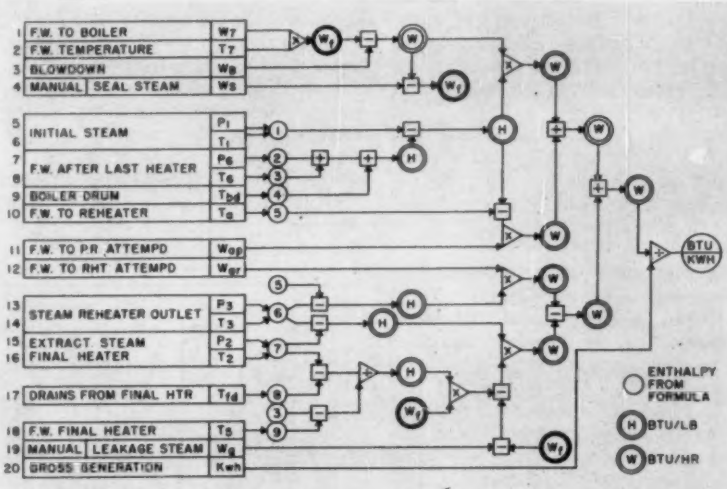
Figure 2 shows the Computer Console, from which the programmer can take over control of any of the machine operations. He can feed a tape program into the high-speed reader and change any part of the on-line program in Channel 2 or any of its data constants. He can also feed a program into Channel 1 and perform independent calculations without conflicting with the operator at the other console.

He can use data stored in the memory by Channel 2, and work it as though it were a plant simulator since this data is stored in separate buffers to which he has complete access. He does not have to perform any complex programming maneuvers to keep his program from mixing with the Channel 2 program.

An additional precaution is incorporated to make this time-sharing safe and practical. This is an automatic lockout that prevents the programmer from accidentally changing the program of Channel 2, due to a mistake in entering his program for Channel 1. This store lockout is switched in by the programmer when a Channel 1 program is to be entered. This automatically segregates a selected part of unused memory space for Channel 1, and while this switch is closed, it is impossible to enter or change the on-line Channel 2 program.

This makes it possible to de-bug or check out a new program routine while the machine is continuously monitoring the plant, with no interruption and no danger.

Of course, adequate memory is required, and for this reason, all ISI-609 machines are now equipped with a 160,000-bit quick access memory, as in Table II.


1 F.W. TO BOILER W7
2 F.W. TEMPERATURE T7
3 BLOWDOWN W8
4 MANUAL SEAL STEAM W5
5 INITIAL STEAM P1
6 T1
7 F.W. AFTER LAST HEATER P6
8 T6
9 BOILER DRUM Tbd
10 F.W. TO REHEATER T5
11 F.W. TO PR ATTEMPD Wap
12 F.W. TO RHT ATTEMPD War
13 STEAM REHEATER OUTLET P3
14 T3
15 EXTRACT STEAM P2
16 FINAL HEATER T2
17 DRAINS FROM FINAL HTR Tfd
18 F.W. FINAL HEATER T5
19 MANUAL LEAKAGE STEAM W9
20 GROSS GENERATION Kwh
BTU KWH
ENTHALPY FROM FORMULA
H BTU/LB
W BTU/HR

$$h = F + 0.043557\left[F_0P + \frac{B_0}{2}\left(\frac{P}{T}\right)2\left\{-B_6 + B_0\left[B_2 - B_2 + 2B_7\frac{B_0}{2}\left(\frac{P}{T}\right)2\right]\right\}\right]$$

P = pressure = p/14.6959 = int atmos, abs.

T = temperature, deg Kelvin = $255.38 + \frac{5}{9}t$

$B_0 = 1.89 - B_1$

$B_1 = \frac{2641.62\ 10^{8870/T^2}}{T}$

$B_2 = 82.546$

$B_3 = \frac{162460}{T}$

$B_4 = 0.21828T$

$B_5 = \frac{126970}{T}$

$B_6 = B_0B_3 - 2F_0\,(B_2 - B_3)$

$B_7 = 2F_0\,(B_4 - B_5) - B_0B_5$

$F_0 = 1.89 - B_1\left(\frac{372420}{T^2} + 2\right)$

$F = \frac{775.596}{\log_{10}T} + 0.63296T + 0.000162467T^2 + 47.3635$

Fig. 3. Diagram of computer calculation, Gross Turbine Heat Rate. Each double circle is a complex enthalpy equation like one shown. Nine equations involved use up 300 memory words. Computer completes computation in 0.5 second

Automatic Start-Stop

. . . eliminating human error

CHANGING SHAPES . . .

By LUKAS F. KENNEDY

Mr. Kennedy is Manager of System Protection and Control Engineering in General Electric Co's User Industrial Sales Dept, a post held since 1950. He graduated in Electrical Engineering from Rensselaer Polytechnic Institute in 1922, joined G E that year on the test engineering program. He has been a member of Central Station Engineering Staff since 1939, specializing in supervisory control engineering; belongs to AIEE, CIGRE, NEMA

WITH THE INTENSE interest shown today in steam station automation, it is amazing to realize that several decades have passed since the first installations of automatic hydro stations. Superficially, at least, both involve a similar sequence: start, accelerate, synchronize, and load.

However, in the automatic hydro station, the actual operation is practically as simple as the foregoing description, and it can be accomplished with a minimum complement of relays.

On the other hand, problems encountered in a steam station are so much more complicated that they cannot be simply described but must be covered by some degree of classification such as the following:

A. Need for controlled rates of warm-up for both the boiler and turbine-generator to avoid excess stress due to temperature differentials.

B. Adequate control of fuel, air, ignition, and feedwater under starting and running conditions.

C. Control and/or monitoring of condenser, heat exchangers, and water-conditioning systems.

D. Control of literally hundreds of important functions such as steam seals, drains, lubricants, coolers, and the like.

E. Monitoring, calculation and corrective action from hundreds of measurements of temperature, pressure, flow, etc, of fuel, air, water, steam, lubricants, and electrical quantities.

Very complexity of the task of automating the steam-electric generating station is, by itself, one of the most compelling reasons for seeking a means of accomplishing it.

Human operator finds it practically impossible to assimilate hundreds of items of data and to make logical decisions. Manual operation has succeeded only because relatively few items are simultaneously significant.

Larger units, utilizing higher steam temperatures and pressures and conductor-cooled generators, lead to necessity for closer control of critical variables, together with a greater number of essential measurements. All of this makes it increasingly difficult for the human operator to perform effectively, even under expected normal operating conditions.

Many engineers have recognized the desirability of extending automatic operation to steam stations. In fact, a start was made in 1937, when plans were made to utilize a relay system similar to the usual hydro station practices, to control automatically a turbine-generator from starting to synchronizing. This equipment was installed on the Ohio Power Co Unit No. 7 at Windsor Station in 1939. Some detailed equipment difficulties plus World War II prevented this from ever being placed in continuous operation.

Fig. 1. Human operators find it increasingly difficult to assimilate hundreds of items of data and make logical decisions, a compelling reason for automating

It is important to point out here that the establishment of turbine-generator starting and stopping sequence is only a minor part of steam station automation.

Full scope of steam station automation requires much more than merely establishing sequences. Each portion or step of the cycle, from the initial boiler firing-through to on-line operation above minimum load, requires control in response to measurements so that optimum performance may be achieved.

Stored-program digital computer has many desirable features: it can assimilate a tremendous amount of data, make logical decisions based on the stored program, issue commands, and perform precise calculations. In fact, its capability is limited only by the know-how and imagination of its human programmer. Once programmed, it will always do what it has been instructed to do. Since it has a greater data-assimilating capability than a man, it is the equivalent of having on duty continuously a team of ideal operators.

As an example of what needs to be accomplished, Table II is a condensed sequence for a normal start of a boiler-turbine-generator unit. List shown is intended primarily as a guide to the kinds of operations that must be programmed. Each item on this list may in turn involve several steps, including check of measured variables in comparison with programmed limits, and checks of position

Similar sequences would be prepared for hot start, normal shutdown, and emergency shutdown. In addition to start-up and shutdown procedures, there also would be programs for corrective action during normal running conditions.

Complete installation of the stored-program digital computer will require that the computer be capable of scanning several hundred analog quantities, several hundred contact positions, have several hundred contact outputs, and 10–30 analog outputs. It also will provide for alarms, alarm print-out, trend recorders, periodic and on-demand print-out.

Automation of hydro stations easily can be proved on an economic basis. Added cost of automation is relatively insignificant; saving in manpower alone pays for the equipment.

Case for steam station automation is not so simple. There are many areas of potential economic advantage, but the value in any specific case is not always easy to determine. However, this author and his associates, like many other people in the industry, are quite convinced that the automation of steam-electric generating stations is certain to be universally accepted within a relatively few years.

Some of the areas of potential gain are listed below with some figures as to possible gains.

In submitting these figures, it is realized that they may not meet with universal agreement, but they do provide a method whereby others can draw their own conclusions.

1. Reduced possibility of catastrophic damage to equipment due to human operating error. This is one of the most difficult to evaluate. The man who daily manipulates his way through a dangerous intersection without an accident is convinced the statistics do not apply to him. However, mistakes do happen, and the elimination of just one would pay for automation many times over.

2. Reduction of outages due to operating errors. Outages due to operating errors seldom directly cause equipment damage, although they may lead to such damage in the subsequent confusion of trying to get back to normal operating conditions. However, outages due to operating errors also may lead to severe service interruptions with possible loss of revenue and customer good will. This is difficult to evaluate in dollars. Many operating people have given this as one of their main reasons for considering automation desirable.

3. Reduction in maintenance through more precise control of operating conditions. Precise control will eliminate undue stresses due to excessive rates of change of temperature, pressure, and the like. With annual maintenance costs in the range of $1 to $5 per kw, even relatively small improvements justify capital investment of $0.50 to $1 per kw.

4. Reduction in forced-outage rate. Precise control which reduces maintenance also should be reflected in a reduction in forced-outage rate, and this can be given a value based on reduced reserve requirements. For example, if we assume that we can reduce the forced-outage rate from 2 per cent to 1¼ per cent, this would mean that the reserve requirements could be reduced by 1 per cent, which can be evaluated at $1.50 per kw of unit rating.

5. Improved fuel economy through up-to-the-minute data on actual operating heat rates. Most utilities today have either manual or automatic dispatching systems to achieve optimum fuel economy through loading in accordance with incremental cost techniques. Possible savings through further refinement of these procedures, using up-to-date information, appear to offer significant savings. Too, plant economy may be improved when data is immediately available. These savings cannot be estimated accurately at the moment, although studies are currently under way. On the basis of preliminary information, savings of ¼ to 1 per cent appear possible.

6. Reduction in operating personnel. Automation should make it possible to operate a plant with fewer personnel. While opinions as to the extent of such reductions vary, a sav-

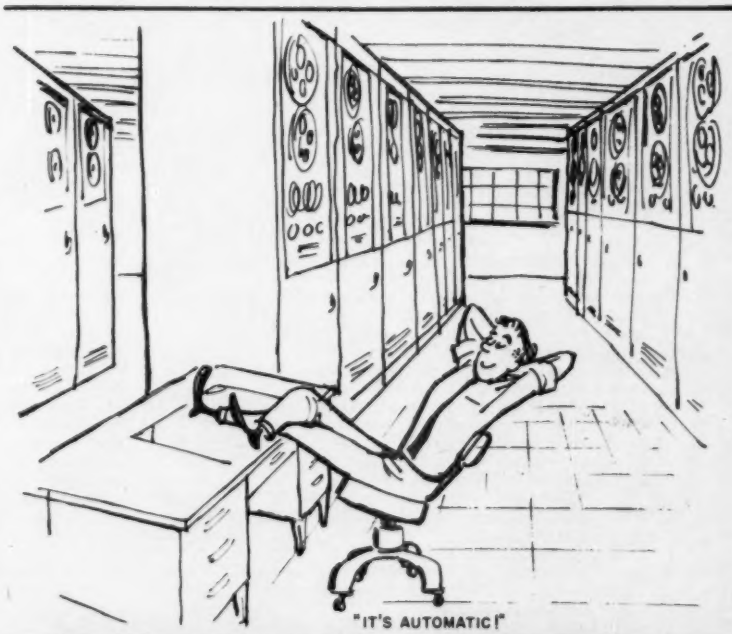


Fig. 2. Stored-program computer has many desirable features: it can assimilate data, make logical decisions, issue commands, and perform precise calculations

ing of one operator round-the-clock seems to be reasonable with a capitalized value of $150,000 to $200,000. In addition, there are also available some manpower savings representing that now devoted to manual calculation of heat rate from presently available log sheets or instrument records.

7. There are some additional advantages which provide further justification for automation, such as the complete, integrated, and continuous alarm system; savings from the replacement of recording instruments by data-logging; and some reduced need for highly-skilled operating personnel. In connection with the continuous alarm system, it is worthwhile to report that there have been two cases where the prompt alarm has alerted operators in time to prevent possible serious damage.

Table I, which refers to both a 200-mw and a 500-mw unit, sums up these advantages in terms of *possible* capitalized value where estimates are available, but does not attempt to establish any dollar value for items 1 and 2. These are classed as intangibles.

Since published figures have indicated that full automation may add $700,000 to $1,000,000 to conventional plant costs, this tabulation shows that automation is within the range of economic feasibility, even without giving a specific dollar value to the intangibles covered by items 1 and 2.

Future experience will permit a closer evaluation of these potential savings. We believe that such an evaluation will show that the intangible benefit of better operation completely justifies automation.

Table I. Tabulation for 200-mw and 500-mw unit sums up economic advantage

	Dollars, In Thousands	
	200 mw	500 mw
1. Catastrophic damage		
2. Reduced outage (operating errors)		
3. Reduced maintenance ($0.50 to $1.00)	100–200	250–500
4. Reduced forced-outage ($0.75 to $1.50)	150–300	375–750
5. Improved economy (per cent to 1 per cent)	50–200	125–500
6. Personnel	150–200	150–200
7. Miscellaneous (instrument credit)	50–50	50–50
Total	500–950	950–2000

Table II. Condensed sequence for normal start of a generating unit, a sample of the kinds of operations to be programmed

BOILER AND CONDENSER

1. Put in operation plant service supply systems:
   a. Auxiliary power supply and distribution system
   b. Service water
   c. Station air (with its cooling water supply)
   d. Instrument air (with its cooling water supply)
   e. Fuel system
2. Check the following:
   a. Water level in steam drum correct for start-up Reduce, if necessary, for swell compensation by blowdown
   b. Accessories, valves, inspection doors etc, ready
   c. Air vents on steam drum, open
   d. Superheater and reheater drains, open
   e. Dampers and/or vanes in air supply and flue gas circuit and burner air registers, open
   f. Extraction valves, closed
3. Purge the boiler
   a. Start 1 induced-draft fan
   b. Start 1 forced-draft fan
   c. Purge for 5 to 20 minutes
4. Boiler warm-up
   a. Inactivate automatic combustion control
   b. Set dampers, vanes, and burner registers for firing
   c. Position and light-off burners
   d. Start air heaters
   e. Insert probes to check superheater tube temperature
   f. Check rate of rise of critical metal temperature, and regulate firing to keep within limits
   g. Open warm-up by-passes to condenser for establishing steam flow through superheater and reheater
5. Activate condenser
   a. Position valves, vents, etc for circulating water
   b. Prime pump, pipes, and tunnels
   c. Start circulating-water pump and open discharge
   d. Check traveling screens and start:
      1. Trash racks if necessary
      2. Screen wash if necessary
      3. Chlorination system as required
      4. De-icing gate as required
   e. Evacuate condenser after establishing steam seals on turbine
   f. Evacuate extraction heaters
6. Activate condenser and boiler feedwater systems
   a. Position valves, vents, etc, for condensate
   b. Start condensate pump
   c. Position valves, vents, etc, for boiler feedwater
   d. Start boiler feed pump
   e. Open by-pass around feedwater regulator to activate start-up drum level controller
7. Boiler warm-up and load
   a. Put burners in service as required
   b. Activate feedwater regulator
   c. Inactivate start-up drum level controller
   d. Activate combustion controller
   e. Check that extraction valves are open
   f. Close vents and drains
   g. Shut off warm-up by-pass to condenser
   h. Remove temperature probes
   i. Energize precipitators
   j. Start feedwater treatment, continuous blowdown, etc.
   k. Operate soot-blowers, dust-collecting system as required
   l. Start second forced- and induced-draft fans
   m. Start second boiler feed pump as required
   n. Transfer auxiliary power supply to transformer on generator leads

TURBINE-GENERATOR

8. Prepare for start
   a. Check and position valves
   b. Activate lube oil temperature regulator
   c. Check rotor and lube oil temperature
   d. Start pumps, fans, other auxiliaries as necessary
   e. Check emergency d-c oil pump operation
9. Put on turning gear. Operation timed so machine will be on turning gear 60 minutes before rolling unit with steam
10. Warm-up
    a. Start condenser auxiliaries and establish vacuum
    b. Establish steam seals
    c. Check auxiliary oil pump
    d. Check and position valves as necessary
    e. Warm-up valve sheet
11. Start. Check eccentricity. Start unit with steam and accelerate at programmed rate under supervision of differential temperature, vibration, eccentricity, and differential expansion measurements. Programmed corrective action to be taken as necessary. Apply excitation and transfer to speed governor
12. Synchronize and load
    a. Synchronize with system and load in accordance with programmed rate, which will be a function of steam and metal temperatures
    b. Start and stop accessories and auxiliaries; position valves for normal operation

Push-Button Operation:

. . . the ultimate in control?

CHANGING SHAPES . . .

By W. A. SUMMERS

Mr. Summers holds a degree in Chemical Engineering from Cooper Union School of Engineering. He is active as a Naval Reserve instructor in theory of maintenance of electronic equipment. Since 1948 he has been in the employ of Ebasco Services, is presently working on automation of Louisiana Power & Light's gas-fired Little Gypsy automatic steam-electric station and an unannounced automatic coal-fired station

IN TODAY'S rapidly changing field of power plant control, it is certain that the automatic operation being designed today is definitely not the ultimate for our industry.

Ultimate is a power system which integrates completely automatic units, automatic system operation, proper information measurement and transmittal equipment, unit sizes, and power transmission equipment into an operating system that minimizes the delivered cost of power while producing reasonable profits.

Today such a system must remain as a challenge in the future. Necessary parts of the ultimate system, however, are being built today. One of the necessary steps is power plant automation.

Stripped of all fancy phrases, the job of an automatic power plant is to start, run and stop itself, in a safe, reliable, and efficient manner to meet the power demands imposed upon it. Automation of this scope might add three-quarter million dollars to the cost of a modern large gas-fired plant, and proportionately more to a coal-fired plant.

This automation must be engineered for full-time operation. It must cover all periods of plant operation. It must be capable of handling a steady load, normal or rapid load changes, emergencies caused by equipment or system failure, emergency shutdowns, and variations in water or fuel conditions.

Automatic start-stop is an integral part of any automatic plant. Start-stop is mainly concerned with sequences, safety, and proper treatment of equipment for a relatively few hours each year (but hours with higher accident rates than during normal operation). On-line automatic operation, some 8000 hours per year, is also concerned with safety and proper handling and care of equipment, but with two additions: supervision and economics of operation.

It is easier to understand the functions of an automatic plant operation or any operation if the operating steps are broken down. The way in which decisions are made and orders carried out are sketched in Fig. 2.

1. An uncontrolled variable, such as a load change, or auxiliary equipment failure, affects the process of converting fuel to electricity.

2. These effects are sensed by changes in measured variables — for example, steam pressure, gas burner pressure, equipment status, and so on.

3. Measurements must be collected, combined, and scaled (data reduction) to produce significant information (steam pressure low, gas pressure high, one burner out).

4. Information is then compared with norms, formulas, past history, or patterns stored in a "memory." Such an evaluation will lead to a conclusion or decision. For instance, the decision may call for starting an adtional burner on one side.

5. Safest and most suitable method of carrying out the decision must be chosen from all those available to the "operator." A decision to light an inoperative burner is not admissible, and any burner capable of working

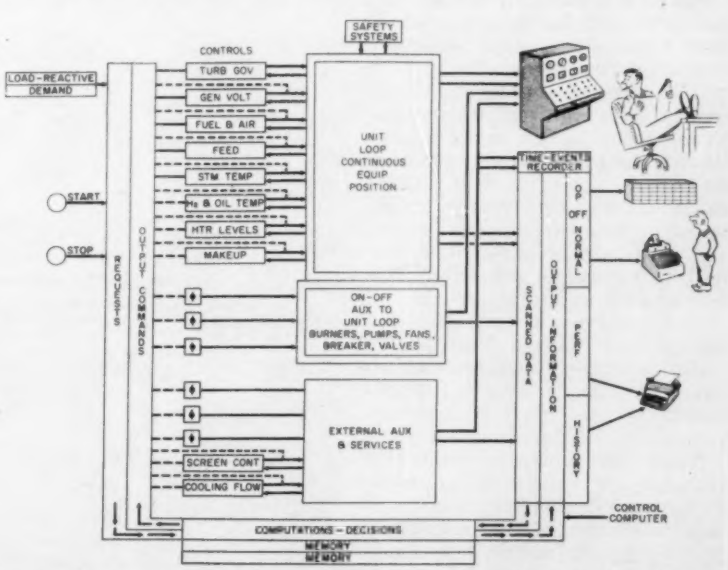


Fig. 1. Diagram shows how a computer acts to control a generating plant

must be used, even though it may not be in the best position. Further steps may be required to compensate for the selection made, such as maintaining the ignition source, if the second-choice burner is far removed from other operating burners.

6. Method selected may also involve many sub-steps and many pieces of plant equipment. Each step must be executed correctly at the proper rate and time to effect changes in the controllable variables in order to restore the process to its desired condition.

7. As this loop control proceeds, records must be made of information, decisions and commands. This step-by-step method applies to a simple operation or a complex operation.

Where a single plant variable, or a limited number, is directly controlled by a few devices with limited decisions and correction methods, a continuous control loop accomplishes the routine. For example, if steam pressure is to be maintained at a fixed value, or if generator voltage is to be kept constant, a continuous regulator or simple control loop is used.

When the task is to "run the plant," including its numerous regulating controls or sub-loops, the operating steps are the same. However, the amount of information to be considered, the amount of "memory" required, the number of methods needed, and the amount of equipment under control all increase rapidly, while the time permitted for making each decision is reduced. In short, a complex of abilities similar to those of a man, but without emotions, and with greater consistency and a lower rate of error, is required.

Figure 1 shows how a computer can serve such functions in a plant. Two tasks differentiate automatic control from start-stop:

1. Supervision of running equipment to meet load requirements safely and reliably. This includes positioning, starting or stopping auxiliary equipment, rapid deduction of difficulties, selection of corrective action, testing of safety and backup devices.

2. Economics of operation to meet load requirements efficiently. This encompasses generation of the required power with a minimum of fuel and auxiliary power, reduction of major equipment maintenance, increased availability of unit, and detection of the loss from operation without the required maintenance.

Supervision is also concerned with the approach to limits of equipment, starting and stopping auxiliary equipment to meet load demands, and with proper regulating action of the many sub-loop control systems.

A generating unit should not be permitted to operate outside of its thermal limits, even though the system of external control signals may request such operation. If such operation is requested, a compromise must be reached between unusual system demands and protection of plant equipment through proper operation.

Computing systems could calculate the present allowable limits for the operating hydrogen pressure and reactive, calculate the kva from load and reactive, and compare the actual with the design limits.

Computing control can permit these excursions, but if the power system requests do not bring the unit back to limits in the allotted time, the load and/or reactive must be automatically reduced to return the unit to a safe operating area. Such pre-planned actions can be held ready and instituted within seconds, based on flexible, variable limits.

Another important aspect of the automatic supervision would be a constant monitoring of a sub-loop control, such as combustion, feedwater, steam temperature, generator voltage, etc, Fig. 3. Even with good maintenance, such control systems occasionally function improperly, and it is the duty of the supervising control (the plant operator in present plants) to take over control of that variable when the automatic system or sub-loop fails.

This action can be taken by a control computer which, in effect, would place the troubled variable on "hand control" and gradually regulate the final drive to produce desired control actions. It is also probable that some of these actions would require that the generating unit be removed from load control, either base-loaded or put on restricted load control, so that variations would not occur faster than compensations could be made.

This ability to put sub-loop controls on computer "hand" is one of the differentiating factors between a fully-automatic plant and a sequentially programmed unit.

If the trouble is not in the control system but in the final actuator, the master control system must use alternate means, such as spare pumps or alternate routing, to achieve the desired controlled actions.

If all of these fail, then the only alternative is to remove the unit from service, or operate it at a load permitted by the present position of the final control element.

One of the advantages that accrues in such supervisory control is that relationships of numerous variables can be digested rapidly by a computing type system. It can predict the occurrence of difficulties before they become uncontrollable, permitting a reasonable attempt to be made to correct the system before dangerous conditions arise.

This is "feed forward" control, which calculates what the error would be if a given change is made, and then compensates operation for that expected error. For instance, instruction for a radical load change would be converted into setpoint and dynamic changes for all plant controls and equipment at the same time or even slightly before the instruction to the turbine generator.

One difficulty that must be provided for, and detected, is failure of the supervisor. With a human operator this is difficult until his actions upset the plant seriously enough to actuate the safety systems and trip

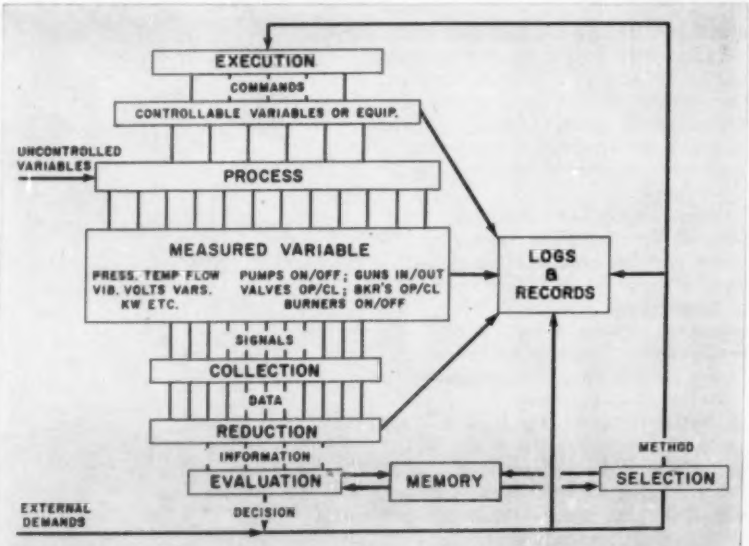


Fig. 2. Chart showing way decisions are made and executed in automatic plant

the unit. Basic techniques have been developed which will permit a control computer to monitor itself to a far greater degree than its human counterpart. These techniques, coupled with a "mental" deadman's switch, will cause the master control computer to relinquish control when its decision-making ability is not working.

Although manpower savings may be important in some plants, the capitalized value of manpower savings may be eclipsed by the value of fast, proper action to reduce damage or maintain generation. Years of automatic operation will be needed to establish such criteria.

Other apparent economic advantages of automatic operation come from better regulation and continually correct economic choices in the operation of plant equipment. Savings may be realized from decreased maintenance for major equipment, and smaller amounts of fuel burned for a given load.

Ability of a computer control system to operate and supervise many auxiliaries almost simultaneously should increase the plant's ability to meet load demands within equipment design limits. Yet this ability to meet load demands sometimes requires the plant to exceed desirable rates of change on major equipment. Again, these two goals are at odds with each other. Preplanned judgment and compromise are needed. Use of computer control allows preplanned compromises based on the best judgment of manufacturers, operators, and engineers who can evaluate the probable effects and determine the degree that the limits shall be exceeded and the time duration in order to achieve this additional load-meeting ability.

During programming, such decisions can be made with due consideration of all aspects, rather than under the stress of facing an operating decision in the control room.

A computer does not substitute for engineering and operating judgment. Instead, it forces such judgments to be made on a sound technical basis before the case arises.

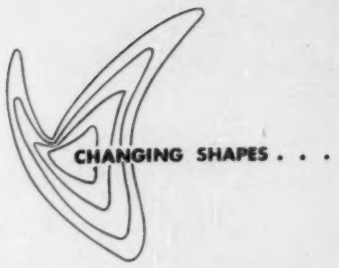
Much has been written in recent years about the use of a computer to optimize operation. Many experts in the field cannot agree on the terms to be used, much less a definition of the terms. You will find used the words *optimize, optimalize, adaptive, self-adaptive*, and many others.

Today, we can slice through the confusion of these terms and apply a limited definition of optimum operation for power plant control. Our definition will be to generate the required power with the minimum practical fuel input for the existing uncontrolled conditions of ambient temperatures, fuel, and circulating water. This can be realized by:

1. Frequent calculation of actual plant and major equipment performance; 2. comparison to previous heat performance; 3., a, adjusting the set points of control systems within the plant, b, positioning, starting or stopping auxiliary equipment to burn the least fuel for the required load within safety and equipment design limitations; 4. adjusting control response (that is, proportional band, reset, and rate settings) to minimize the deviations from control points previously selected. These adjustments would be a function of the load the equipment is carrying and the dynamic action of the major equipment.

Optimization requires the ability to sense a change in plant economic performance as a result of an operating change. Effectiveness of such a method is limited by the ability to reproduce measurements; thus the technique of storing calibration curves, computing corrections for expansion, Reynolds number, hysteresis, etc, which improve the reproducibility of results, all aid in achieving improved performance.

In a modern non-controlled extraction turbine-generator cycle, relatively little can be done to the turbine-generator to effect a reduction in heat rate, except to minimize internal fouling or damage. Most of the control of cycle efficiency is obtained through control of the boiler cycle and condenser to produce steam inlet-outlet conditions that will optimize turbine-generator performance. Another area subject to improvement in heat rate is the operation of plant auxiliaries in such a manner that auxiliary power usage is minimized.



A most valuable relationship that must be constantly updated is the "heat rate vs load" curve of the unit, and its derivative, the incremental heat-rate curve. Frequent transmission of this relationship to load control computers would permit system loading to be made on a more realistic basis than by today's methods.

Translation of these potential capabilities into an operating reality is a tremendous engineering job requiring the coöperative efforts of plant equipment suppliers, control companies, operating companies, designers, and constructors. At the recent ISA Utility Data Handling Workshop in Chicago, it was estimated that the combined engineering effort of all participants would be 5–10 man-years for the early automation projects.

In the foreground of this effort is the promise of rapid, faultless, and faithful execution of operation instructions; yet in the background is full awareness that such an operating machine will, with equal faithfulness, execute any "wrong" instructions. Part of the increased cost of automation today is the effort required to produce the "right" instructions.

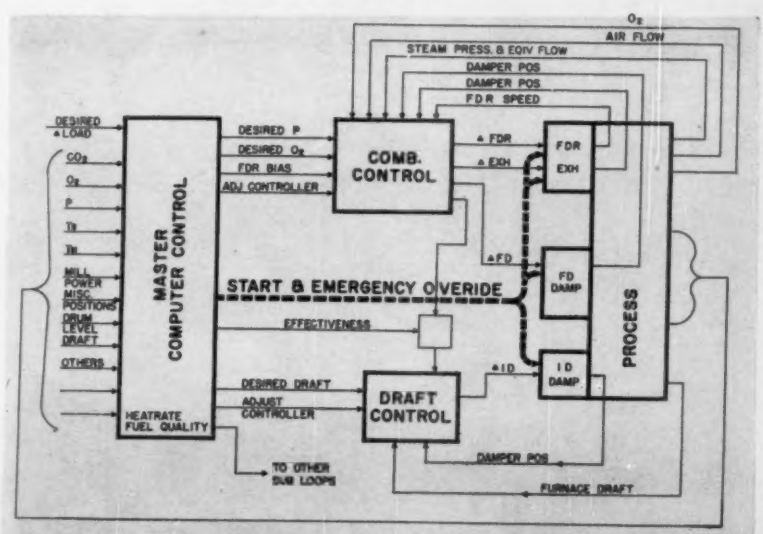


Fig. 3. Diagram of constant monitoring of sub-loops in the automatic plant

Economic Power Dispatch
. . the automatic systems approach

CHANGING SHAPES . . .

By NATHAN COHN

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THERE ARE PERHAPS few things that are taken more for granted nowadays than the supply of electric power. A flick of the switch, at the time of need, and the utility customer expects the modern genie of electric energy to light up his home, operate his appliances, or run his industrial plant.

Continuity of service, matching total supply to total demand, is thus the cardinal objective in power systems operation. But economy of production is also an important operating objective. It has been receiving increasing attention in recent times.

Modern generating stations are equipped with a variety of instruments and automatic controls aimed at minimizing production costs. More developments in automatic techniques can be expected that will further improve individual station performance. But there is another aspect of power systems operation that can be an important source of savings. This has to do with the over-all coördination of system operation, looking at all of the stations of a given area as related parts of a single control problem, and correlating the operations of all of them with respect to one another to achieve optimum over-all economy.

For example, the cost of producing the total amount of power needed by an area at any given time depends on which of the available generating sources are used and how they are loaded. Allocating the total properly among available sources can yield major savings at the coal pile.

Determining what the total area generation ought to be, what the most desirable allocation among sources should be, and achieving these conditions is a complex production control problem. It involves many simultaneously changing variables, usually at widely separated locations, making it very difficult for operators to deal manually with the matter. It can very readily be handled, however, by modern automatic area-wide computer-control systems. It is indeed being very effectively done by such automatic means day in and day out on many of the country's power systems. The process is referred to as "automatic economy dispatch."

One way to emphasize the scope and nature of a modern automatic economy dispatch system is to follow a slender thread back to the work of an University of Glasgow instrument maker in the latter part of the 18th century, almost a hundred years before the genius of Thomas Edison

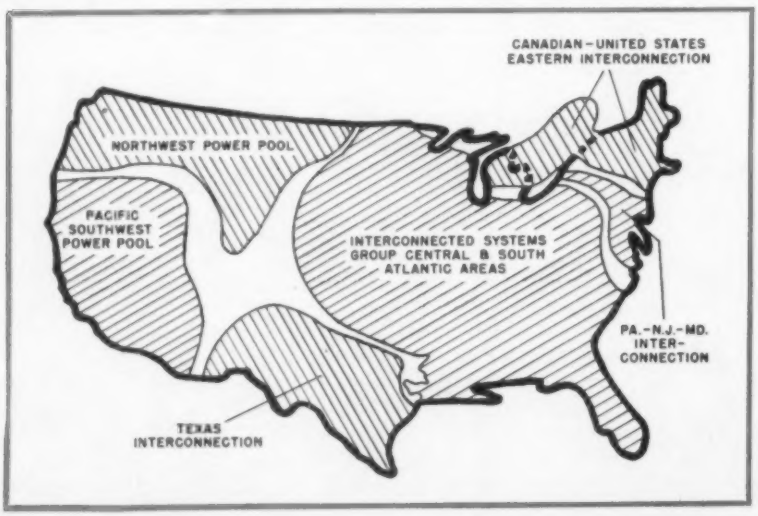


Fig. 1 (Left). Areas covered by major interconnections described in text

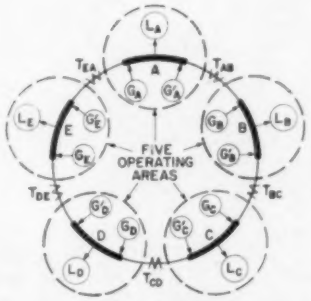


Fig. 2 (Above). Simplified diagram of an interconnected power system. Each area adjusts generation to own load

created the electric power industry. James Watt was the man and, appropriately enough, his name has become a household word as the unit of electric power. If there is a single patron saint for modern power systems control technology, it is he.

Back in 1788, Watt had developed the steam engine beyond the crudities of his predecessors, and was about to speed the Industrial Revolution in Britain and the world. He had the problem of providing a reliable control for his engine. Specifically, his problem — like that of our modern power systems — was that of matching supply to demand. He solved it by inventing the flyball governor, a pioneer achievement in automation. With it, energy input to his engine was automatically matched to output demand.

It is, of course, an oversimplification to compare Mr. Watt's input-output problem with the matching of input and output on a modern power system. There are massive differences between what he had to do and what needs now to be done. Examining the similarities and the differences, however, will give us a better view of some of the things an automatic economy dispatch system must accomplish. Indeed, Mr. Watt's governor, though refined and improved a thousandfold, is still a part of today's solution.

Important point to note is this: Mr. Watt had to concern himself with only one engine at a time. His governor matched input to demand for just that one machine. On a present-day interconnected power system, on the other hand, there may be dozens or even hundreds of generating units acting in concert to satisfy aggregate customer demand. Each unit has a governor based on Watt's principle, and in the aggregate all the governors act to match aggregate input to aggregate demand. That's where Watt's contribution ends and the modern problem begins. Specifically, how shall each source be given an appropriate part of the total demand so that the best over-all economy can be achieved while turning out the required total generation?

Modern power systems embrace extensive areas. Adjacent utilities interconnect so that they can share generation and reserves, and thereby achieve improved reliability and economy.

There are six major interconnections in the United States and Eastern Canada, as shown in Fig. 1. Large Central and South Atlantic Group, for example, includes almost a hundred major utilities operating hundreds of individual generating sources.

Tie-lines between interconnected utilities are usually many and complex, but for a look at basic control concepts we can represent a typical interconnection by the simplified diagram of Fig. 2. Here each of the five utilities is assumed to have its own single load, L, two generating sources, G and G′, and a tie with each of its two neighbors.

Let's assume that each of the five operating companies shown in the diagram is to adjust its generation to follow its own demand changes, a typical objective on such a multiple-area interconnection. Now let's see what the operating problems are.

First, there is the need for making sure that the sum total of all of the generation of the entire five-company interconnection matches the aggregate demand of all customers on the interconnection. That step will insure continuity of service for all customers. It is achieved, as already noted, by the aggregate action on all generating sources of today's counterparts of Mr. Watt's governor.

Second, there is the need for allocating the proper part of this total system generation to each of the five areas. That's done by automatically checking *exports* or *imports* over

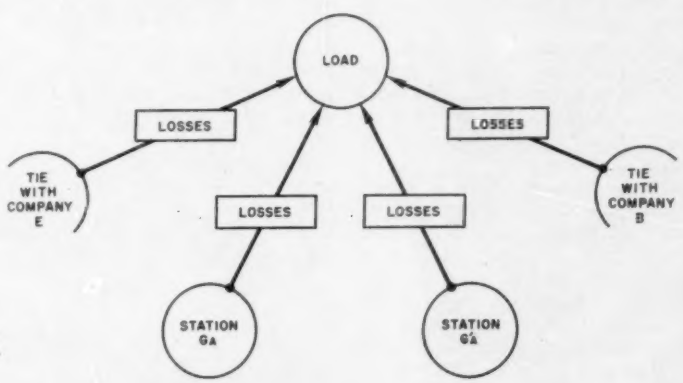


Fig. 3. Diagram showing how area load changes are accommodated by economy dispatch computer considering fuel costs, source efficiencies, and line losses

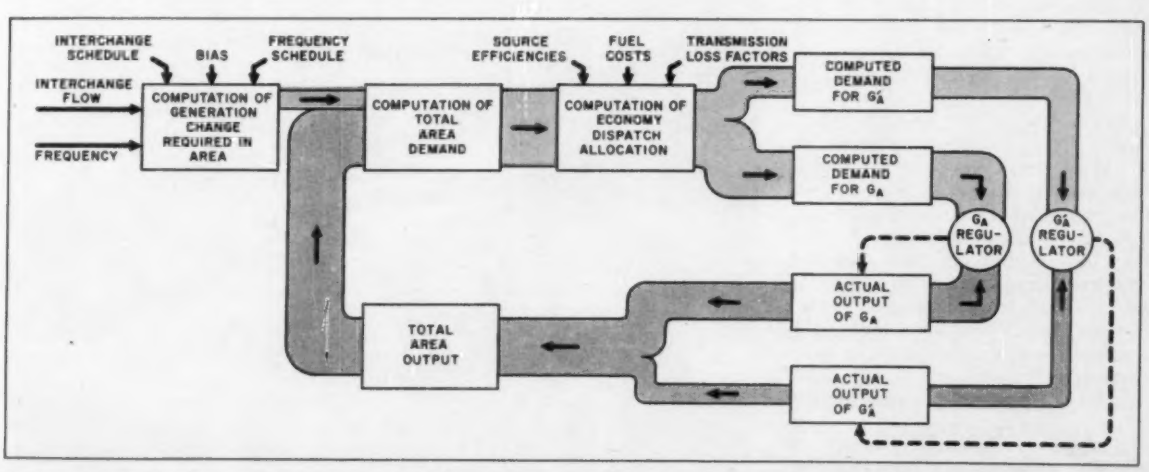


Fig. 4. Simplified diagram of economy dispatch computer control with total area supply matched to total area demand

boundary ties to neighbors and adjusting area generation to keep these tieline flows on schedule. If each company does this, it will in fact be adjusting its own generation to satisfy its own customer demand.

Third, there is the opportunity to so allocate the total generation of the company area among its available generating sources so as to get the required total area generation with minimum cost at the coal pile. Here is where today's economy dispatch computer-control systems make their biggest contribution. A typically-sized company may have a coal bill of 20 to 30 millions of dollars or more per year. It clearly does not require a large percentage saving to justify an appreciable investment in an economy dispatch system.

When it comes to deciding where to allocate area load changes for lowest cost, the electronic brain of the economy dispatch computer has to consider a number of factors.

Think of the load of Company A of Fig. 2 being served as shown in Fig. 3. Generation, for example, may come from the company's plant GA or from its plant G'A. Now GA may be a new plant with better efficiency for the next needed unit of power than could be achieved at plant G'A, so a first thought is that the next increment of load should be picked up at GA.

Perhaps, however, G'A is closer to a lower cost source of fuel, so that actually the dollar cost of generating the next unit of power at G'A is really cheaper than at the more efficient plant GA, so G'A ought to get the nod. But then, perhaps there is a greater transmission loss in getting from plant G'A to the load than would be the case from plant GA to the load. Now, though it costs more to generate the next unit of power at GA, the power that actually would be delivered to the load from GA may have a lower net cost than the same amount of additional power delivered to the load from G'A. So we're back to GA as our choice.

But maybe getting the next unit of power from neighbor company E would be even cheaper at the load L than getting it from station GA. Or maybe it would be still cheaper to get it from neighbor company B, who may be in a different time zone and who may have some extra power for sale at a cost, even allowing for transmission losses, lower than any of the available sources of Company A or Company E could deliver the same increment of power to load L at that time.

Simplified schematic diagram of the way an automatic economy dispatch computer-control does this job on a two-unit area such as Company A of Fig. 2 is shown in Fig. 4.

There is first an automatic computation of area demand. There is then an economy dispatch computation which determines what the demand should be on each of the available sources. Total of these source demands, of course, must equal the total area demand. A regulator for each source then automatically insures that the output from that source matches the computed demand for that source.

With this accomplished, it follows that the sum of the source outputs, or the total area supply, then equals the total area demand. Customer loads have been served and power has been delivered to them at lowest possible cost.

Problem is, of course, considerably more complex than is shown in Figs. 2, 3, or 4 when one considers the many alternative generating sources beyond two that a typical company has, the varying fuel costs for them, the varying transmission losses with different area loading conditions, the fact that some generating units may be limited in their load carrying capacity because of prevailing special conditions, and the possibility that some units may at that time be down for maintenance or otherwise not available.

An economy dispatch computer is designed to handle these complexities. Certain pertinent information is stored in it. Other data on system conditions are continuously fed to it over direct wire, carrier, or microwave channels from plants and tielines, which may be dozens or hundreds of miles away, and out of it comes computed data and automatic orders that tell each generating source what level of loading it is to carry so that area demand is fulfilled and optimum economy is achieved.

One of the newest of the country's automatic economy dispatch computers, one of a dozen such systems now in operation or being built, is shown in Fig. 5. This is a photograph of the Florida Power & Light Company's dispatching center at Miami. Here the economy dispatch computer controller performs functions similar to those illustrated in Fig. 4. It computes and achieves optimum economy loading of the company's 10 stations and 26 generating units while monitoring and controlling net power flow over the company's tielines with its neighbors.

Present-day economy dispatch computer controls like this one can do many magic things automatically and dependably. They make real contributions to continuity of service and also to minimum cost of production.

They have come a long way from Mr. Watt's governor. They let a utility take a look at its complete system, not just a part of it, and provide automatic coördination of all of its operating sources, a giant step forward in the power industry's use of automation as part of its advancing technology.

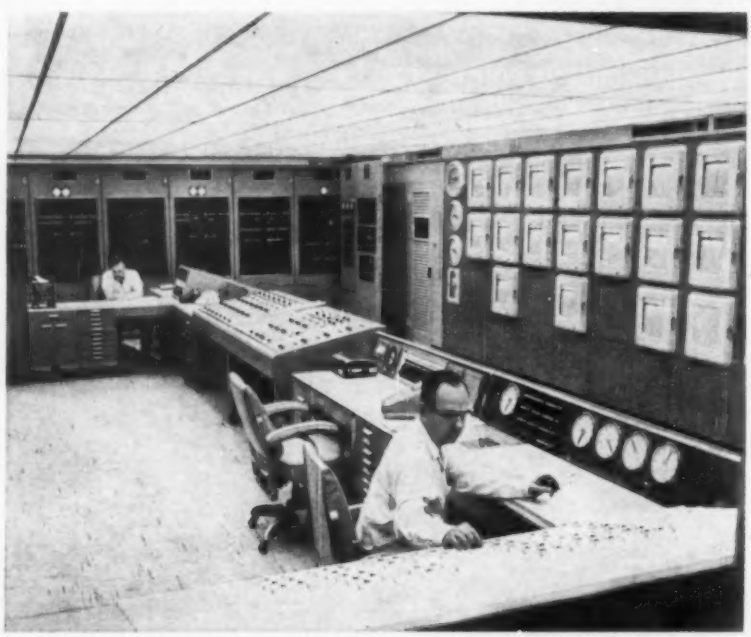


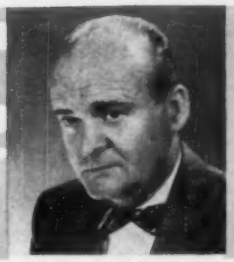
Fig. 5. Photo of Florida Power & Light Company's dispatching center in Miami

CHANGING SHAPES . . .

Automatic Plants Mean New Control Concepts

Part I of a Two-part Series

By WALTER A. HICKOX



Mr. Hickox, graduate physicist of Case Institute of Technology is Controls Systems Consultant with Combustion Engineering, Inc. Formerly with Norden Laboratories and Sperry Gyroscope, he participated in development of fire-control systems, computers, precision, transducers, and aircraft autopilots. He has 20 years' experience in the controls field, has been responsible for development of much significant military hardware

IS THE EFFORT now being expended toward the design of an automatic power plant directed along the proper channels? For those programs in their infancy, an objective appraisal is premature; for those which have progressed to a point where the concept is definite and published, the misdirection is apparent.

One of the first boiler controls was regulation of feedwater to maintain drum level. From this modest beginning, additional controls were successively applied to maintain steam pressure and temperature, furnace pressure and so on, finally resulting in today's complex control systems for the typical, large power plants. Today's generating stations have control rooms full of indicators, recorders and controls, as well as some sort of controller at almost every conceivable point in the cycle.

Control systems which have resulted from this process of evolution are, unfortunately, needlessly complex, unreliable, and contain many redundant features. These controls are not integrated, but operate independently at selected points in the process. They also utilize non-uniform display and recording systems which are difficult to interpret and are, therefore, conducive to reading errors and misinterpretations of results.

In almost all other areas of endeavor, rapidly increasing knowledge is soon put to use to update the state of the art, and latest techniques are constantly being exploited. In the industrial control field, however, we seriously lag the present state of the art and seem reluctant to adopt a revised or new approach to the inevitable automatic power plant.

What, then, causes the commercial control industry to cling so tenaciously to the present antiquated concepts?

Responsibility for this situation must be distributed among the principal participants: major equipment suppliers, controls manufacturers, public utility bodies, and the consulting engineers. Underlying reason for this technical inertia is the lack of a systems concept. The perceptive editors of POWER ENGINEERING requested that this article be written from the "boiler point of view," with the thought in mind, no doubt, that the heart of the problem should be the most sensitive to it.

We are already overburdened with manufacturers of different component parts presenting individual points of view on a systems problem. Therefore, this text has been prepared and the proposed control system based on the very broad *systems point of view*, rather than a discussion of components and minor control loops.

This lack of an over-all systems concept is clearly illustrated by a superficial analysis of several controls, representative of today's practice:

Present feedwater controls, for example, are still based on drum level with modifying signals from steam flow and feedwater flow. The really basic, yes fundamental, requirement is to supply feedwater at a rate that matches the megawatts demanded from the system and *not* to maintain a hypothetically correct drum level. We recognize the inclusion of drum internals imposes limitations on permissible drum level variations, but this is not the principal role of feedwater control.

Similarly, present superheater outlet temperature controls only generate corrective action *after* the occurrence of a temperature deviation. The real objective, and this concept is a basic one, is actually to prevent excessive temperature excursions above or below design temperatures.

Typical combustion control, like all other controls, has grown like Topsy and controls only isolated system variables. It adjusts fuel to maintain steam pressure, instead of supplying the correct amount of fuel to match the load requirement (actually its primary responsibility). In addition, these typical controls, because of their limited function, maintain a fixed output regardless of load variations in the area. This is contrary to the often-stated axiom of the ideal power generating source that it is the responsibility of each plant to absorb the load changes in its own area.

The successive application of one control after another has created an unwieldy assortment of equipment having poor reliability. Control manufacturers and the major equipment suppliers apparently have not recognized this. Therefore, not one has established a position whereby he can assume, as someone should, complete responsibility for a system that transforms fuel into megawatts.

Instead, because of the increasing complexity of control systems, the individual manufacturer has become engrossed in his own problems of equipment performance and individual minor control loop actions.

Public utilities and consulting engineers have, perforce, attempted systems engineering without the necessary staff, research facilities, or familiarity with fundamental forms of servo mechanisms or servo systems. Without the all-important systems approach, it is apparent why control manufacturers still are being called upon to bid for and furnish isolated portions of a control system. Further, control manufacturers are also presented with a plant of fixed design, and hence are forced to use control points selected without due consideration or appreciation of the control requirements imposed.

Under these confused circumstances, control manufacturers haphazardly proceed to assemble varied assortments of incompatible black boxes under the name of control system. Further, these manufacturers have little or no knowledge of the dynamic characteristics of the over-all cycle or the performance of control equipment separately furnished. As a direct result, control manufacturers cannot be aware of any interactions or the effect of these interactions on control of the cycle.

A control system thus assembled usually contains an odd mixture of pneumatic and electrical indicators, recorders, and controllers. Such a mixture even exists in single minor control loops, and thus dictates use of electric to pneumatic and pneumatic to electric converters. Use of such unnecessary components is obviously unjustified. Components necessary to eliminate signal conversion *can* be developed, since the applicable techniques have been known for some time.

Obviously, a control system so assembled is needlessly complex, expensive, and can only be much less reliable than a simplified, well-engineered system.

In the past decade, we have developed and put to use such useful engineering tools as analog and digital computers, differential analyzers, X-Y plotters, and the like. In addition, advanced techniques in servomechanism design and analysis and systems engineering have been developed in the same period. *We have failed to put any of these tools or techniques to any extensive use to improve industrial control systems.*

Some of the more forward-looking utilities are becoming aware of the antiquated control concepts in general use today, and as a result, several automation studies are now underway. If these can be kept on an objective basis, real benefits are bound to accrue. However, it is apparently natural for those who are not up to date on *all* latest developments in computing and control techniques to assume, after being exposed to the current flood of propaganda concerning general-purpose digital computers, that this is the final answer to an automatic plant. To superimpose a digital computer on top of presently outmoded, inaccurate, and sluggish controls merely compounds the problems; certainly it is no simplification!

At least one automatic plant utilizing the above concept has been authorized, and another station at present utilizes the digital computer for data-logging. It is interesting to note that a portable analog data-logging system with equivalent capacity is available at a cost of about one-seventh of the reported figure for the data-logger purchased.

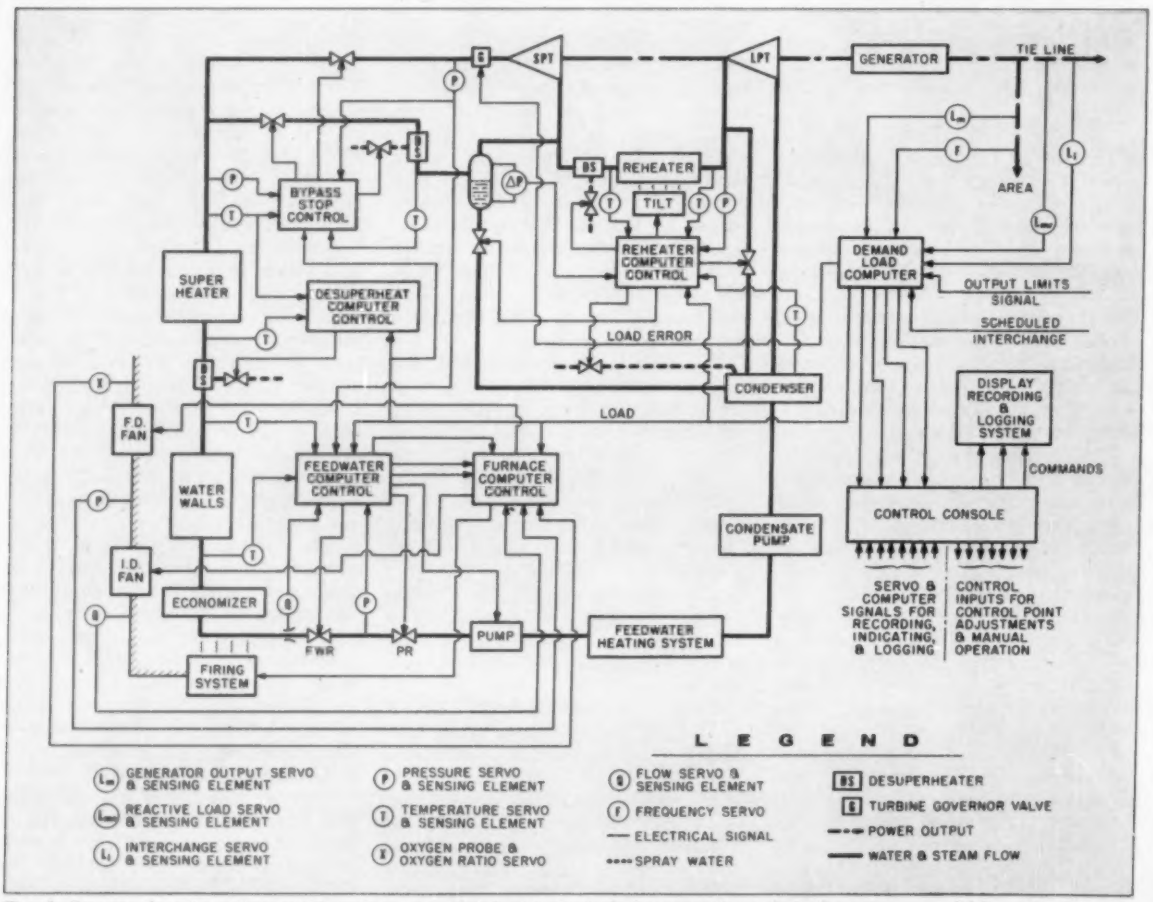


Fig. 1. Proposed automatic control system, completely integrated, for once-through boiler serving a 325-mw installation

Both digital and analog computers have a place in our growing economy. Each has definite functions which it can most accurately and efficiently perform. Each type of system will function best and be the most economical method in its own environment, but to attempt to interchange their places or use either one as a Jack-of-all-Trades is asking for trouble and unwarranted additional expense. A general-purpose digital computer is a valuable research and laboratory tool, and should be cared for in the same manner as any piece of precision laboratory equipment. Obviously, a power plant does not qualify as a suitable environment for this type of equipment.

Magnitude of the problem facing us, and the futility of present approaches to its solution, now becomes quite obvious. What, then, is the approach to the design of the automatic power plant?

The only reasonable approach is to retire mentally the present control systems and embark upon the development of a completely new, properly-engineered system. In addition, the electric utilities should be prepared also to contract for the entire plant with one organization willing and able to accept complete system responsibility.

An extensive, purely objective study program, including a reappraisal of the entire problem, must precede development of a new instrumentation and control system for an automatic plant. This study should include complete simulation of the entire system on a computer of suitable capacity, as well as a suitable test program to completely verify accuracy of the simulation. After such a simulation has been provided, it then becomes a simple matter to thoroughly investigate new control systems, changes to the boiler, turbine, and start-up and shut-down procedures.

Specifications can then be established which will fully describe the plant and controls. Simulation can also determine the relative importance of presently indicated and recorded parameters so as to simplify the control panel. Concurrently with the simulation and dynamic analysis portions of the study, a detailed Human Engineering study should be made concerning the operator's activities and demands on his time in a plant automated to several different degrees.

These studies, when combined with other feasibility and economic studies, should quickly define for us the degree of automation desirable for the foreseeable future.

Those who are unfamiliar with computer simulation techniques cannot fully appreciate the usefulness of the tool. It is equivalent to having a complete full-size power plant and control system purely for research with an unlimited amount of capital to make alterations and improvements to the boiler, the turbine, and the controls. It has an outstanding advantage over an actual pilot power plant in that such changes or alterations can be made rapidly at little or no cost.

Let us now look briefly at the type of control system which should be the objective of such a development program. General design concept for such an automatic plant control is, that for a given change in "Demand Load," either scheduled or non-scheduled, all of the required input parameters are computed and applied immediately to the system by means of the controls. Feedback in all cases is either temperature, flow, pressure, and the like, and not final control element position, since we are computing the actual required effect on the final control element. Automatic start-up, shut-down, and the like are to be programmed based on monitored conditions of the system, and not upon a pure time basis.

This control system is essentially "computer control" and can, because of reliability, economics, and sound systems engineering considerations, best be accomplished through an analog computer.

Computer control, as applied in the following proposed system, has two important advantages. Control problems caused by excessive system variation are minimized and the control parameters are prevented from excessive variation, rather than corrected at some finite time after a measured excursion has occurred. Features of the author's proposed system are as follows:

Logging of data is *on command* or *continuous* when desired. Storage of data to be only in the form of strip charts or typed log sheets. All sequences and programs are based on intelligence from control system and automatically selected. System uses dust- and moisture-proof potentiometers rather than slidewires, and these are used only in computing circuits. Data and position transmission is by means of synchros. All final control element servos are electric motor-driven or if necessary, electrically-actuated, high-speed, high-pressure hydraulic servos.

Primary data is continuously recorded on strip charts 60 days long. Secondary data is indicated only, with considerable switching for strip chart recording of secondary data if desired. Logging capability is provided for either or both primary and secondary data.

Entire control, display, recording, logging, and computing systems consist of plug-in units requiring no calibration or alignment. Primary sensors are accurate to within 0.1 per cent and have time constants of less than one second.

Servo and computing amplifiers are encapsulated for protection against humidity and dust. All plug-in modules are sealed against dust and moisture, and do not use batteries or standard cells. System uses only magnetic amplifiers and transistors; it uses no electronic tubes.

Primary transducers are located as close as possible to control point and use electrical signals for transmission of intelligence to control room and computer. System contains limited capacity for computing necessary performance from available data.

System uses simplified oxygen analyzer with sensing elements located in the gas stream. Sensing elements and probe separate fly-ash from flue gas without decrease in temperature, thus improving response and eliminating corrosion problems.

System uses reduced-size indicators and recorders arranged for integrated display in related functional groups on control panel. Indicators are provided with automatically-positioned control point index as a visual check on control system performance. Error larger than predetermined tolerance energizes alarm system. Recorders use electro-sensitive paper and stylus instead of pen and ink.

Pneumatic-type equipment is completely eliminated.

Proposed control system is based on the assumption that it is the responsibility of each plant to absorb load changes in its own area and maintain frequency. Each plant need only transmit to the dispatcher the current load capability and the area load. Dispatcher, in turn, transmits to each plant the scheduled interchange.

Demand load is defined as generator output plus interchange error plus a constant times frequency error. The frequency term is added only to

provide intelligence necessary for discriminating between load changes in the area and outside the area. There are two modes of operation: "Demand Load Follow" and "Fixed Output."

Fixed Output mode is provided in case the unit should be required to operate base-loaded, and also for programming purposes during start-up and shutdown. Control system is completely integrated, and is shown for a super-critical once-through unit in Fig. 1. Figure 2 separates what is currently known as the combustion control system, for the sake of clarity.

In all loops, the feedback signal is the desired result, and not control element position. Note that in this combustion control system, there exists only one control interaction, as compared with as many as eight in present day systems.

Control system actually consists of six different sub-systems, five of which are used for computer-type control and have the common primary input of Demand Load. These sub-systems are: 1. Feedwater Computer Control; 2. Furnace Computer Control; 3. Desuperheater Computer Control; 4. By-pass Stop Control; 5. Reheat Computer Control; and 6. Demand Load Computer.

All of the control sub-systems compute the result desired of the final control element action and actuate the control element to achieve this result, using the measured result as feedback.

Feedwater computer determines required feedwater flow from waterwall inlet temperature, outlet temperature, and demand load, and provides a control signal to the regulating valve until measured flow matches required flow. A control signal is also sent to the feedwater pressure regulating valve, thus matching required pressure to measured pressure. Required feedwater pressure is computed from measured pressure drop and desired steam pressure at the turbine inlet, thus automatically compensating for variation of pressure drop with load.

Furnace computer control computes the required absorbed heat and matches this quantity to measured absorbed heat by adjusting the firing rate. Required boiler air flow is computed from load and oxygen ratio and compared to measured air flow to provide a control signal for the induced-draft fan. Since furnace pressure is invariant with load, no load intelligence is required in this loop. A control signal to the forced-draft fan is generated by an error signal between required furnace pressure and measured furnace pressure.

Desuperheat computer control computes required superheater inlet temperature from temperature rise through the section, and load. Inlet temperature is measured and compared to the computed value, thus generating an error signal, which is used as a control signal to the spray injection valve, maintaining a constant superheater outlet temperature.

Bypass stop control computes required reheat inlet temperature from load to maintain desired outlet temperature and provides control signals to burner tilt and spray injection valve as required to match either the measured inlet or outlet temperature to desired values. Also included in this sub-system is the required circuitry to generate suitable control signals for operation of the reheater bypass system.

Demand load computer generates signals proportional to demand load, fixed output, and load error as functions of generator output frequency error and interchange error. It also includes memory circuits to prevent exceeding capability of the unit, depending upon the auxiliary equipment available, and provides necessary signal transmission to the load dispatcher.

Data-logging system prints out a typewritten sheet listing all parameters to be logged in a fixed format on demand or periodically. A tape punch is also included in order that data can be fed into and processed by existing IBM computers. Logging is at the rate of one point per second, and suitable means are provided in order that several different logging programs can be utilized at the operators option.

System would also include a combination recording and display arrangement having two important advantages: one, that the operator would have an indication of short-term trends, and two, that by combining indicator and recorder, one less servo for each measured parameter is required than if recording and indicating functions were packaged in separate units.

Vertical scale indicators having resolution equivalent to or greater than present indicators would indicate the desired control point as well as the measured value. Scale would be movable, positioned by the control point servo. By this means, condition of boiler is quickly determined and needed corrections shown.

Preliminary study that resulted in this proposed control system was based on a unit rated at 325 megawatts, with turbine throttle conditions of 3500 psi and 1050 F, and reheat to 1050 F. It is estimated that the controls, board instrumentation and data logger, less the final control element drive units for such a plant, would cost, in production, $435,000, including profit and amortization of development costs.

Description of this control and instrumentation system has been greatly condensed from a report recently prepared by the author containing detailed control system design data for a power station of the above-mentioned capacity. A complete description could not, for obvious reasons, be presented here. However, the author will welcome inquiries from interested parties on any of the features mentioned in the article.

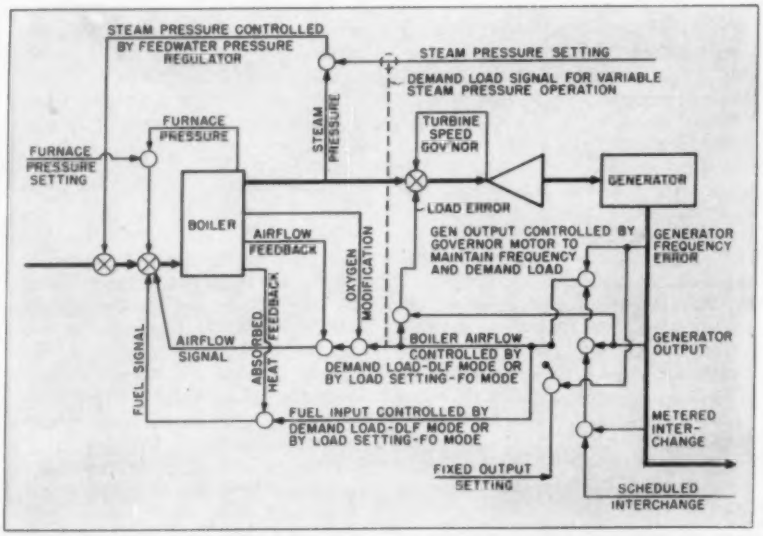

STEAM PRESSURE CONTROLLED BY FEEDWATER PRESSURE REGULATOR
STEAM PRESSURE SETTING
DEMAND LOAD SIGNAL FOR VARIABLE STEAM PRESSURE OPERATION
FURNACE PRESSURE
STEAM PRESSURE
TURBINE SPEED GOVERNOR
FURNACE PRESSURE SETTING
GENERATOR
BOILER
LOAD ERROR
AIRFLOW FEEDBACK
OXYGEN MODIFICATION
GEN OUTPUT CONTROLLED BY GOVERNOR MOTOR TO MAINTAIN FREQUENCY AND DEMAND LOAD
GENERATOR FREQUENCY ERROR
AIRFLOW SIGNAL
ABSORBED HEAT FEEDBACK
FUEL SIGNAL
BOILER AIRFLOW CONTROLLED BY DEMAND LOAD-DLF MODE OR BY LOAD SETTING-FO MODE
GENERATOR OUTPUT
FUEL INPUT CONTROLLED BY DEMAND LOAD-DLF MODE OR BY LOAD SETTING-FO MODE
METERED INTERCHANGE
FIXED OUTPUT SETTING
SCHEDULED INTERCHANGE

Fig. 2. Combustion control system for the integrated control shown in Fig. 1. In all loops, feedback signal is the desired result, not control element position

Automating the Coal-Fired Station: Some Problems to Be Overcome

By JAMES E. TEBAY

Mr. Tebay is Product Line Manager for Beckman Scientific and Process Instruments Div, in charge of such power engineering instrumentation as computer control, flow colorimeters, infra-red analyzers, electrolytic hygrometers, and pH instrumentation. He holds a Bachelor of Science degree in Engineering Physics from University of Colorado. He is a member of Instrument Society of America, Sigma Tau, and Tau Beta Pi

MEASUREMENTS and control of variables which are common to all stations: feedwater and steam cycle, turbine and generator, are omitted from comment here excepting to note that measurement and control of these variables should be explored on gas-fired stations first, due to added complications of coal-firing. Following five limits are defined by the author as a frame of reference:

1. Automatic plant, as envisioned, should be capable of computer control under normal operation as well as automatic cold start-up and shutdown.

2. Coal-firing instrument needs are explored from point of view of the needs of the computer for optimum control, not the needs of the plant for these instruments.

3. Economic aspects of equipment costs versus material return on investment are omitted excepting to say that three main factors involved in the article are increased safety, fuel savings, and labor savings.

4. Plant should be large, capable of over 100 megawatts per unit.

5. Computer shall be integral to the plant with a minimum of duplicated instruments so that the plant will not run manually except for emergency due to a disabled computer.

BEFORE IT IS READY to accept a computer into the control room, the coal-fired steam plant still has some unsolved problems.

While data handling experience has provided accurate and time-correlated data for operators of several large steam plants, the truly automatic plant which starts from a cold boiler operates at peak efficiency over varying load conditions, and shuts down again under control of a computer, is not yet a reality. However, several automatic plants are under construction today, and the coal-fired station under computer control may be the plant of the *near* future.

Four problems seem unique to a coal-fired station. None is new; all present plants now face these same problems to some degree. These are flame-scanning, flue-gas analysis, coal analysis, and coal weighing.

Certainly one of the more serious problems associated with a coal-fired station is the determination of flame at each burner.

Automatic cold starts may be programmed as a series of events for a computer to perform, only after flame handling and measurement have improved. Basically, a flame scanner need only be qualitative but must, at the same time, be specific to the flame from one burner.

Early flame-scanning instruments employed an infra-red detection system. A simple optical system protruded through the furnace wall, focused on a flame so as to direct radiant energy upon a lead sulfide detector. Detector, in turn, operated a contactor or relay which would indicate the presence or absence of flame.

This technique provided a high speed of response and, if properly installed, proved to be relatively trouble-free. Unfortunately, the infra-red analyzer could not be colimated or focused. Thus, the detector had a wide angle of vision with a resulting lack of specificity to one burner. The result was somewhat dangerous since the detector might be reading other burners or incandescent refractory.

Newer technique also scans the flame optically, though in the ultra-violet region. Idea promises to be more successful, since ultra-violet energy from a flame can be focused sharply on the detector.

One idea which may satisfy all requirements for a flame scanner measures thermodynamically rather than photoelectrically. The device might appear as a ceramic button, attached to the burner by a cantilever device. This device will follow the flame at any burner angle, since it would be attached internally to the burner. Ceramic button would contain a resistance wire, which would be one element of a Wheatstone bridge.

One of the advantages of a computer is optimum combustion control over a wide, dynamic range. Only practical means of measuring combustion is to analyze the flue gases.

Analyzers supplied by several manufacturers are presently on the market which could provide reliable, accurate O_2 and CO_2 data for a computer. Problem of analysis with coal-firing centers around the sample handling system: an integrated set of components which extracts a continuous representative sample from the gas passes and feeds the sample back into the analyzer.

Five basic problems must be resolved before continuous truly repre-

sentative sampling can be achieved:

First problem is the construction and location of sampling probes to achieve sample averaging. Present furnace designs are always 20 ft or more in the throat dimension above the superheater. Considerable stratification of flue gas occurs in this throat. Stratification also changes under varying load conditions. Therefore, sample averaging must be employed to insure a representative gas being measured by the analyzer.

Second problem concerns corrosion of the probe, since the dew point of sulfuric acid is in the neighborhood of 300 F. Consequently, dilute sulfuric acid, condensing out of the flue gases, will rapidly corrode probes and sampling tube if measurement is made beyond the economizer.

Third problem germane to gas sampling but unique to coal-fired installations concerns fly ash. Sample handling components must be capable of measuring flue gas while effectively filtering out fly ash.

Fourth problem in flue-gas measurement concerns alteration of the sample itself. Fly ash could be rejected quite effectively with a wet sample-handling system in which a spray of water or steam becomes an effective filter. Under these circumstances, water or condensed steam must be knocked out later in the sample-handling train. This water will carry many dissolved gases down the water-trap drain and effectively alter the sample composition as seen by the analyzer.

Final consideration in the sample-handling system, suitable for steam stations of the future, is over-all response time of the analyzer and sample-handling system. The computer-controlled device, whether it be a milling machine or a steam station, requires either a *feed-forward* or a *feed-back* signal to be effective. In this case the computer requires a prompt feed-back signal from the flue-gas analyzer so as to determine the effect on any changes in the fuel-to-air ratio on loads.

One obvious trend will be toward reduced sample-tube cross sections, which further justify fly ash filtering in the sample probe. Figure 1 suggests a silicon filter which has worked satisfactorily in coal-fired stations.

One of the most important measurements required by the plant control computer will be data stating Btu value of the coal.

This will permit the computer to calculate Btu necessary for a given load condition and drive coal-feed equipment to the proper setting.

Many mechanical, electrical, and chemical gadgets have been proposed to perform the function of coal analysis. For example, one could imagine that a portion of the coal sample would be placed in contact with calcium carbide. The reaction product, acetylene, may be analyzed by infrared technique and free surface moisture of the coal inferred.

Another suggestion for rapid coal analysis is to burn another sample and weigh the ash content remaining. Still another idea might be to coke a portion of the sample, measuring the heat content of the oven gases and weighing the remaining free carbon and ash. Each of these proposals conceivably could be performed continually, though the hardware would be very complicated and subject to a high maintenance schedule. Fortunately all calculations, such as the correction of free carbon for ash content, could be performed by the computer.

Coal weighing is not a measurement created by advent of computer control, as is coal analysis. Crude measurements have been performed for years.

Coal weighing is mentioned in this article only because of the added importance of the measurement to the operation of an automatic plant. Measurements today are accurate only to plus or minus four per cent at best; the norm is substantially worse. If the computer is going to be asked to operate at optimum efficiency and perform calculations, this error must be reduced to plus or minus one-half per cent. Accurate scales for material weighing have been developed in pilot plant studies by the cement industry and to some degree by the ore-extracting industries. Coal-handling equipment manufacturers are quite optimistic about their abilities to provide refined scales which will meet this specification.

Problems described here do not concern the redesign of the furnace or modification of computers presently on the market. If the measurements which integrate the unit to the computer are reliable and accurate, present-day plants can be operated by present-day computers.

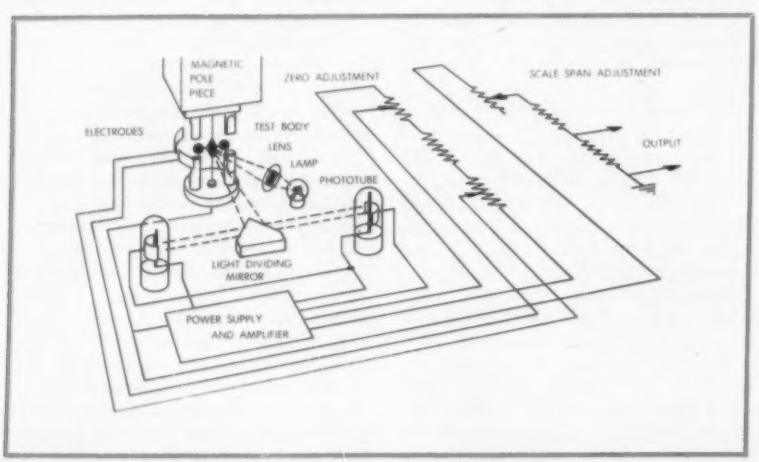


Fig. 1. Schematic diagram of paramagnetic gas analyzer for measurement of O_2 to an accuracy of 0.05 per cent. Analyzer gives millivolt output signal to the computer

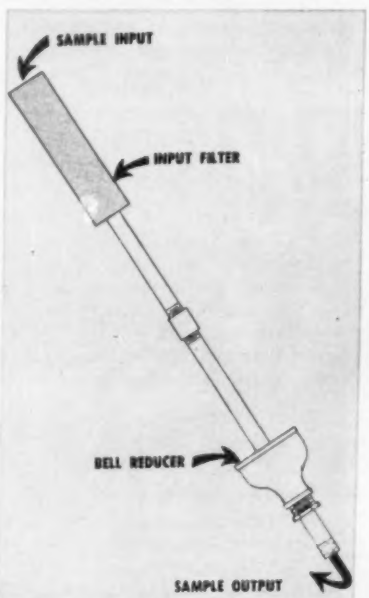


Fig. 2. Gas sampling probe that eliminates fly ash, using the silicon filter

Critical Hardware

. . . A limiting factor

CHANGING SHAPES . . .

By PAUL G. MILLER

Mr. Miller is Assistant General Manager of the Control Systems Div of Daystrom, Inc. After graduating from Purdue in electrical engineering he spent three years at the U. S. Naval Academy, subsequently did post-graduate work in electronics at Massachusetts Institute of Technology. He came to Daystrom from active Naval service as aeronautical engineering duty officer, prior to which he had been engaged in engineering test flying

AT THE PRESENT time, the available digital computers designed for on-line control are not the limiting factor, by several orders of magnitude.

Maximum safe limits of temperature and pressure directly define optimum unit efficiency. In the same manner, accuracy and availability of instruments, and accuracy and sensitivity of positioning control devices directly affect the final increment of efficiency which may be obtained with today's concept of advanced automation through computer control.

Application of digital computer systems to on-line plant operation was not considered feasible three years ago. This was because of technological barriers involved with circuit and component reliability. Now, these barriers have been pushed aside and the power industry is rather suddenly faced with the availability of computer systems that not only meet, but promise to surpass previous industrial reliability standards. Substantiating this is the fact that this type of equipment is at present demonstrating better than 99 per cent operational availability in the field.

In evaluating the benefits that may be gained through the use of digital computers, consideration must be given to the limitations of peripheral equipment which largely consists of conventional instrumentation. Just as metallurgical limitations have governed rise of temperatures and pressures for large steam-generating units, limitations of measurement and analytical transducers and positioning control devices are governing the rate at which computer automation and optimization will approach the ultimate in power plant control.

Computational accuracy of on-line computers is more than a thousand times greater than that of today's best transducers or measuring devices. When switching and analog-to-digital conversion equipment are included, absolute accuracies are still greater by at least an order of magnitude.

Accuracy includes such considerations as zero drift, scale range, linearity, hysteresis (non-linearity due to direction of change), and resolution (sensitivity to small change). Once measurements are converted to numbers in the digital computer system, the accuracy is absolute and limited only by the number of digits carried and operated on.

Critical measurements in power operation include temperature, flow, pressure, and oxygen. Gas flow measurement techniques have not basically improved over many years. Some type of restriction technique is required in order to produce a pressure drop.

Resulting pressure differential is related to flow squared; very poor

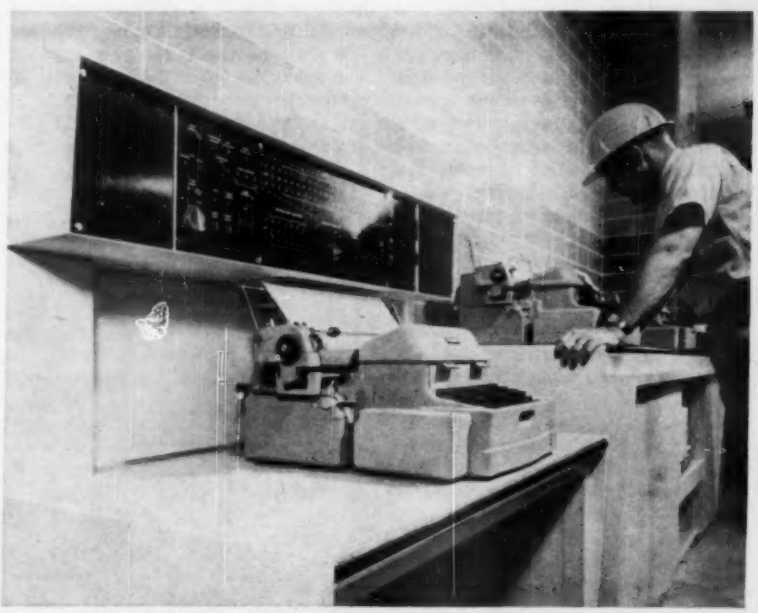


Fig. 1. Daystrom computer system at Sterlington Steam Station is programmed to monitor critical temperatures and pressures and the calorific value of fuel input

sensitivity is inherent in low flow rates.

In addition to this, flow measurements require that temperature and static pressure be measured and their effects calculated. Predictable accuracies are rarely as good as 0.5 per cent and are often as poor as 2.0 per cent or worse.

While the physical sensing problem remains unresolved, computers can materially improve accuracies in computing temperature, pressure and specific gravity effects, plus computing out non-linear and hysteresis characteristics of the primary measuring equipment.

Further, the computer is capable of computing such factors as Btu input on gas-fired units. Calorific value may be measured by a continuous analyzer, and this information made available to the computer system together with temperature, pressure, and specific gravity measurements. A Daystrom computer system operating at the Sterlington Steam Electric Station is programmed for this, as well as the further computation of unit net heat rate in Btu per hour, Fig. 1.

Temperature measurements are for the most part electrical in origin. Therefore, some of the disadvantages inherent in mechanical or motion-type transducers, such as those used for flow and pressure measurement, are eliminated. Thermocouples supply the majority of temperature measurement requirements. While standard thermocouples vary somewhat in characteristics, Bureau of Standards calibrated thermocouples are available for critical measurements.

The computer serves a unique function in the latter case, since the calibrated linearization curves are programmed for each critical temperature measurement. This is the only method of obtaining accurate thermocouple temperature measurements expressed in numerical degrees. This is particularly valuable where temperature values are included in performance calculations.

Considerable progress has been made in the area of analytical instrumentation. However, much remains to be done toward improving maintenance requirements and response times. The very important oxygen analyzer is an excellent example. Sampling techniques present the greatest problem and contribute directly to response time-lag. More accurate definition of this response lag is *dead time*, since no indication of a change in conditions is possible until the sample has reached the analyzer element.

These dead times stymie the computer and are often the critical limiting factor in the dynamic response of the well-instrumented plant.

Positioning control devices such as valve and damper operators require careful consideration when computer systems are used for control purposes. Since the computer system is capable of computing the various parameters of operation with an accuracy of one part in a million, actuator specifications of 0.1 per cent resolution and frequency response 3 db down at 0.5 cycles per second can be well justified.

Communication, in the broad sense of measurement and control signal transmission within the plant, is an important factor in the design of computer-controlled power plants. Since computer systems respond to electrical signals, primary measurement transducers should be of the electronic type.

Fortunately, this instrumentation is available. Some manufacturers have progressed to a point where they are offering completely solid-state devices which promise to be ultra-reliable. On-line computer systems available today never could have received acceptance from a reliability standpoint were they not 100 per cent comprised of solid-state components, approaching infallibility.

Application of computers to conventionally-instrumented plants utilizing pneumatic actuators injects the problem of transducing, or converting pneumatic signals to electric, then back to pneumatic. This can be accomplished by careful selection of transducer equipment. However, this added link in the communication system invariably will downgrade the results to some extent.

The new concept of automatic computer start-up and shutdown, plus automatic emergency action by the computer system, represents a highly significant contribution, since a study has shown that 90 per cent of boiler explosions have been the direct result of human error, and a significant portion of the remaining 10 per cent are attributable to human judgment, Fig. 2.

However, in fully-automated operation, warning devices such as flame detectors carry much heavier responsibility. This represents another area where improvement must be made, and this responsibility again may fall to the systems-engineering organizations.

Industry now has available a reliable computational, decision-making master control computer capable of continuously operating a generating unit very close to the design limit. Regardless of the accuracy, speed, and capability of this "central intelligence" control element, it cannot react to changes in the process which are not detected by the sensing devices feeding it information.

Neither can it effect a change in the process which it senses to be necessary if the actuators, the "muscles" of the system, will not respond.

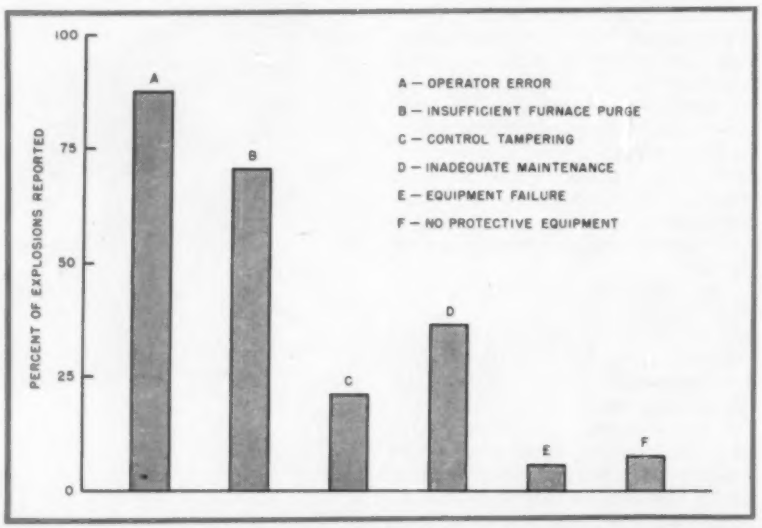


Fig. 2. Chart showing the major causes of boiler explosions; 90 per cent result from human error, remaining 10 per cent largely from errors in human judgment

Automating the Industry

. . . why?
. . . when?
. . . how?

CHANGING SHAPES . . .

By CARL R. FLEMING

Mr. Fleming is Manager of Power Industry Sales Div of The Foxboro Co, holds a degree in Mechanical Engineering from Tufts University. After graduation he joined United Engineers & Constructors and worked on design of central stations and power plant instrumentation, later performed like duties for Jackson & Moreland. He was also involved in compiling and evaluating data for the reactor of the nuclear submarine *Nautilus*

WHY SHOULD AUTOMATION in its various forms interest the modern power engineer? What does it have to offer? What are its untapped potentialities? What are its present limitations?

In the field of power engineering, as in all of the so-called process industries, plant owners and operators have a common concern: how to run their plants most profitably. This, of course, involves lowest first cost to minimize annual fixed charges and reduce annual operating costs. Relative importance of these costs in the industry is apparent from a tabulation showing how each item relates to total annual costs:

Fixed Costs	50%
Operating Costs:	
Fuel	40
Wages	6
Maintenance	4
	100%

It is realized that these percentage figures probably will vary depending upon the type, location, and size of the plant involved.

Stated simply, management is continually endeavoring to run the plant at greatest efficiency throughout its normal load range, consistent with safety of personnel and equipment. Plant efficiency, of course, must be considered in terms of costs per kilowatt produced, rather than just the cost of fuel.

This very often means that desirable and attainable thermal efficiency goals must be compromised in the interests of prolonged life of equipment and reduced annual maintenance costs. Assuming the plant has been successful in developing electric energy at the buss economically, the next problem is to deliver it to the user.

Here, there is equal concern for the over-all economy of the operation as well as continued safety of personnel and equipment, and customer demands for uninterrupted service.

Note that there are two entirely different but inseparably related problems, production and distribution, which must be considered jointly to obtain the best solution for continuously changing conditions.

This, then, is the challenge to the power engineer and instrument manufacturer.

Commercially available equipment and techniques have established a record of accomplishment in this direction, as evidenced by reliability of service and the price at which electric energy is presently available. However, now that load growth curves are becoming steeper and additional generating capacity is being added in larger and larger increments in the form of supercapacity steam generators and ultra-high-capability turbine-generators, present control techniques are rapidly becoming obsolete.

As plant size increases, still another factor emerges. Management is becoming increasingly reluctant to place the responsibility for operation of a highly complex multi-million dollar utility system in the hands of personnel who, after all, are subject to human fallibilities.

Perhaps even more important, from an automatic control standpoint, is the fact that if a man can shut down a plant in an orderly fashion, certainly a machine can be built to do it. The operator may contribute only judgment in considering *when* the shutdown should occur. For the balance of his time, his capabilities are misapplied, or not applied at all. If we can build a machine that decides *when*, then we have a man continuously free for important contributions to the whole plant operation.

This, then, is the basic task for automation today, as it has been since the first day instrumentation was applied to power plant equipment. Only difference is that, under today's economic structure, management is asking instrument engineers to re-evaluate their methods and equipment, and 1. decide whether existing techniques are, in fact, inadequate for the job at hand; and, if so, 2. indicate what direction the extension of automation should take.

At this point, it appears necessary to review factors that are preventing the industry from achieving maximum results in applying existing techniques and equipment to measurement and control problems. These could include the following:

1. Controls fitted to designed plant, rather than design fitted to *controlled plant.*
2. Uncertainties relating to dynamic characteristics of major equipment.
3. Limitations in the measurement of certain critical variables.
4. Tendency to bury lack of knowledge under guise of *reliability,* thus perpetuating outmoded techniques and unrealistic safety factors.
5. Questionable reliability of some components in control systems and primary equipment.
6. Major equipment often not designed to be compatible with modern control.

Leading manufacturers of control equipment have accepted their responsibility and, for years, have been making every effort to improve measuring techniques and reliability of control system components. It is felt that some progress has been made in consideration of the control problem in over-all plant design.

Continued investment of money and manpower should be made in an effort to improve knowledge relating specifically to dynamic characteristics of major heat transfer and generating equipment. Increased effort will be required from those within the power industry if continued progress in this direction is to be assured.

Careful consideration of the items tabulated above would indicate that there is considerable potential for substantially improving existing power plant control without any further consideration of the *fully-automatic plant.*

Gratifying progress toward improved control has been realized through the continually increasing attention being devoted to this subject by forward-thinking segments of the industry. It is certain the results will be self-evident shortly.

In looking to the future, we see that typical plant operations reduced to their simplest form could appear as follows:

A. Start-up, *cold* and *hot.*
B. Shutdown, scheduled and unscheduled.
C. Continuous efficient operation under steady-load and variable-load conditions.
D. Surveying plant variables for:
   1. Accounting purposes
   2. Performance evaluation
   3. Preventive maintenance
   4. Dispatching

Various machinery has been developed under many names, by many people, and in many forms, which purport to perform all the above-named operations. Certainly these operations could be handled by machinery already developed, or being developed at this moment. The power engineer's problem, with which we are concerned here, therefore becomes a question of: **1.** What operations should be automated; **2.** why should these be automated; **3.** how should these be automated; and **4.** when should these be automated?

Considerations relating to adequate answering of these questions are understandably beyond the scope of this article, but certainly many stimulating thoughts on this general subject appear in the associated articles presented in this issue of POWER ENGINEERING. However, a word of caution should be introduced.

Will those factors limiting the potential of present-day control systems be eliminated in the *new* approach to assure final realization of anticipated capabilities? Certainly one should take a critical look at whether or not we have exhausted the potentialities of existing equipment before we consider spending additional monies to extend these capabilities beyond their practical usefulness.

Many of the lessons learned by people rushing to use data-gathering systems should bear fruit in a more studied approach.

Certainly all would agree that it is not the instrumentation that permits the extension to the fully-automated plant, but rather the proper application and utilization of the features built into the instrumentation and equipment. Most sophisticated and dependable control system imaginable is of value only as far as its capabilities can be realized through application.

On this score, it seems incongruous to find users being led in the direction of the fully-automated plant by suppliers who have no instrument application experience in the power field.

While it is certainly true that users are interested in complete automation, they do not seem to be stimulating this trend. If, on the other hand, the power industry were to define its particular automation requirements, then equipment could be oriented toward specific application.

It becomes apparent that some caution must be exercised on the part of the user.

For instance, if a computer is under consideration, the user must have a true computing function for it to perform. It is certainly true that features inherent in computing devices can be applied in other areas such as sequencing, data-gathering, alarm scanning, and the like. However, it is equally true that most of these functions could be more economically performed by devices other than computers.

In considering the application of a computer to a plant, management should adhere to the concept that the function of a computer is to accept data, and from it to develop useful information. Certainly a computer can accept much data, useless in its existing form, and convert it into information that could be useful in the minute-to-minute or daily operation of the power plant. Extent to which this benefit can be realized depends largely on how well the process being evaluated can be reduced to a mathematical model for analysis. Recently announced computing and data-processing equipment have characteristics which permit the purchase of a system to meet immediate needs, yet with the capability of being extended as experience justifies.

As measuring techniques improve, as knowledge of dynamic characteristics of the processes under control increases, and as the computing control approach permits continued refinement in the ability to maintain process variables within design limits, only then will there be complete realization of true computer potential.

This will permit reducing initial plant investment considerably. The plant designer can establish, within very close tolerances, what the possible excursion of process variables will be, and therefore reduce significantly the area of existing ignorance which currently necessitates upgrading and over-engineering.

Here, then, is the real gain as a result of the total effort. We see finally a plant designed because one knows beforehand how it can be controlled, rather than the present-day approach of designing the plant and only then realizing what the control limitations on it will be.

This is real progress: the result of complete process analysis, intelligent definition of automation objectives, and appropriate application of the most advanced instrumentation to the process.

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A LIMITED QUANTITY of reprints of this special report are available while the supply lasts. Single copies will be mailed free of charge to those readers requesting them on their company letterhead, UNTIL FEBRUARY 1. AFTER THAT DATE, REGULAR PRICE OF $1.00 WILL PREVAIL. Quantity lots are available at minimum cost. Our production department will be glad to quote on such quantities. Simply address your request on your letterhead to:

The Editors; POWER ENGINEERING
308 East James St.; Barrington, Illinois

THIS IS AN INVITATION TO THOSE WHO ARE INTERESTED IN COMPUTERS.

Come and sit in this chair. Set up Panellit's ISI 609 Process Information & Computer System to your type of problem. Compare its performance with large scale computers. Question Panellit engineers and computer men to your heart's content.

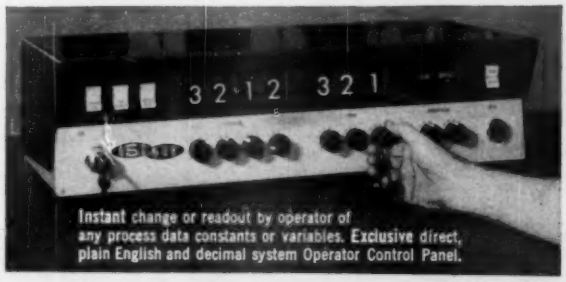
Whatever you decide, yours will be an informed decision.

A COMPUTER MAN CAN DECIDE

FOR YOUR PRELIMINARY INFORMATION, HERE ARE SOME DESCRIPTIVE FACTS:

The ISI 609 is a solid state general purpose computer with internally stored program of exceptional versatility which can be directly coupled to your process. The machine can be used simultaneously for:

1. ON-LINE—Monitoring, Data Processing, Performance Analysis and Control.
2. OFF-LINE—General Purpose Analysis. Entirely Separate from ON-LINE Operation.
3. OFF-LINE analysis using ON-LINE data stored in memory. Study your process without interference with daily operation, in effect utilizing your entire plant as a full scale research project.



Instant change or readout by operator of any process data constants or variables. Exclusive direct, plain English and decimal system Operator Control Panel.

ISI 609 HAS FEATURES COMMON TO LARGE SCALE COMPUTERS, INCLUDING:

1. Comprehensive Order Code—Multi-Programming Capability—4096 B-Line Registers.
2. Automatic Program Modification and Time Sharing. Separate Operator Control Console and Computer Control Console.
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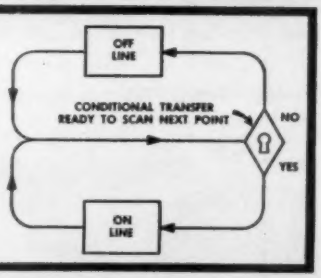
4. Fast arithmetic (e.g., 2.8 m.s. square root or multiplication.)

Stored data constants and operating programs can be changed during operation without stopping the computer. Program can be automatically modified by external occurrences, or as directed by operator.

Background data: ISI 609's complete process Information System was developed by Panellit, Inc., leader in information & control systems. Computer section was developed by Elliott Automation, Ltd., leading British computer manufacturer.

Automatic ON-LINE, OFF-LINE *Time Sharing*.

Exclusive Memory Lockout permits *Time Sharing* during OFF-LINE Operation, with Complete Security of the ON-LINE Data.



WRITE FOR ADVANCE TECHNICAL BULLETIN giving additional details. Panellit Offices or Representatives in Principal Cities are available to help you. You are invited to test ISI 609 at the Skokie plant and to make your own informed decision.

ISI **INFORMATION SYSTEMS, INC.**

7350 North Ridgeway Avenue • Skokie, Illinois

formerly Panascan Div. of PANELLIT

For more data circle 526 on Post Card

EQUIPMENT FOR AUTOMATION

Described here are recent developments in systems, components, instruments and controls to further the use of automation in power engineering. Use the Reader Service Cards to get more information. Circle item numbers of products in which you are interested.

1—SMALL COMPUTER does complex calculations

Performance of more than 100,000 calculations a minute is claimed for the 1620 Data Processing System, a transistorized computer developed by International Business Machines Corp. It takes up little more space than a desk, needs no air conditioning, and operates under the direction of an internally stored program of instructions. It can perform engineering and scientific computations on a continuous or production basis. It consists of two modular units, a central processing unit and a paper tape reader and punch. It performs arithmetic and logical input-output operations on a production basis. Conventional arithmetic is used.

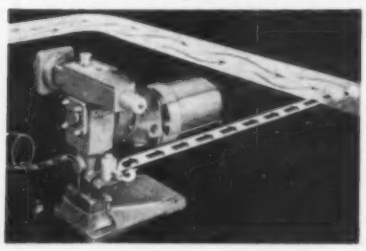
Advanced features incorporated include 20,000 digits of magnetic core storage with variable field length and immediate accessibility, and paper tape and electric typewriter input and output. Availability of two advanced programming systems and a comprehensive library of mathematical and statistical routines simplifies programming. (Specific programs will be available for utilities.) First of these systems are expected to be delivered late next year, at an anticipated cost under $75,000 or on a rental basis of $1,600 a month.

2—CABINETS for control, computer components

Electrical systems cabinets offered by Bailey Meter Co. are designed in accordance with two major trends — automatic data gathering and processing, performance computing and electrically operated control systems; and the control room concept wherein operator has only the instruments necessary to supervise automatic operation and control the unit manually under emergency and off-normal conditions. These cabinets, located apart from the control center, house components of electrical control, performance computing and/or data logging. In this location, there is no need for miniaturization, it is pointed out, and adequate space is provided for maintenance and checkout. Control action units and data reduction modules plug into multi-terminal connectors. Interunit wiring is point-to-point in a single plane. Field wiring is brought into a separate wiring area, often into its own standard cabinet.

3—METERING PUMP is compact, packless

The Pneumatic Stroke Controlled McCannameter, according to its manufacturer, Hills-McCanna Co., automatically proportions chemicals to any main line flow. Utilizing its pneumatic stroke controlled instrumentation, pump is designed to maintain a constant discharge in proportion to the main line flow. Operating on a 3 to 15 psig air signal, the instrument requires no additional power source of air; it is said to respond instantaneously to eliminate back-flash and to maintain the chemical-discharge-to-flow ratio.

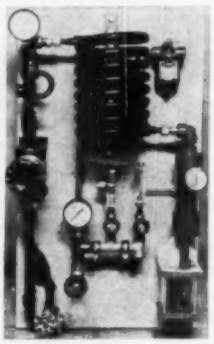


4—TEMP DETECTOR is multi-point monitor

Instead of sensing temperatures only at several pre-determined points, the Line Temperature Detector, developed by Fenwal, Inc., is designed to respond to thermal conditions over its entire length — serving as a multi-point monitor covering an infinite number of points. Operation is based on temperature resistance relationship of selected eutectic salt mixtures which, packed in an Inconel tube, surround a nickel wire center conductor. When temperature reaches a set point, a short circuit is caused between center conductor and outer tube which, in turn, is sensed by a control unit to actuate an alarm or other working device. The tubing may be bent to practically any configuration, as illustrated along with control unit. Standard elements may be connected in series to lengths of several hundred feet, and in one system several temperatures can be detected. Eight available temperatures range from 255 to 1200 F.

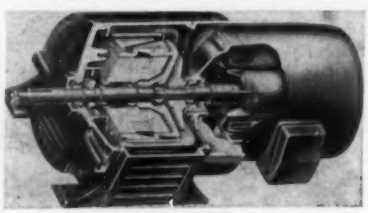
5—GAS SAMPLERS to suit plant requirements

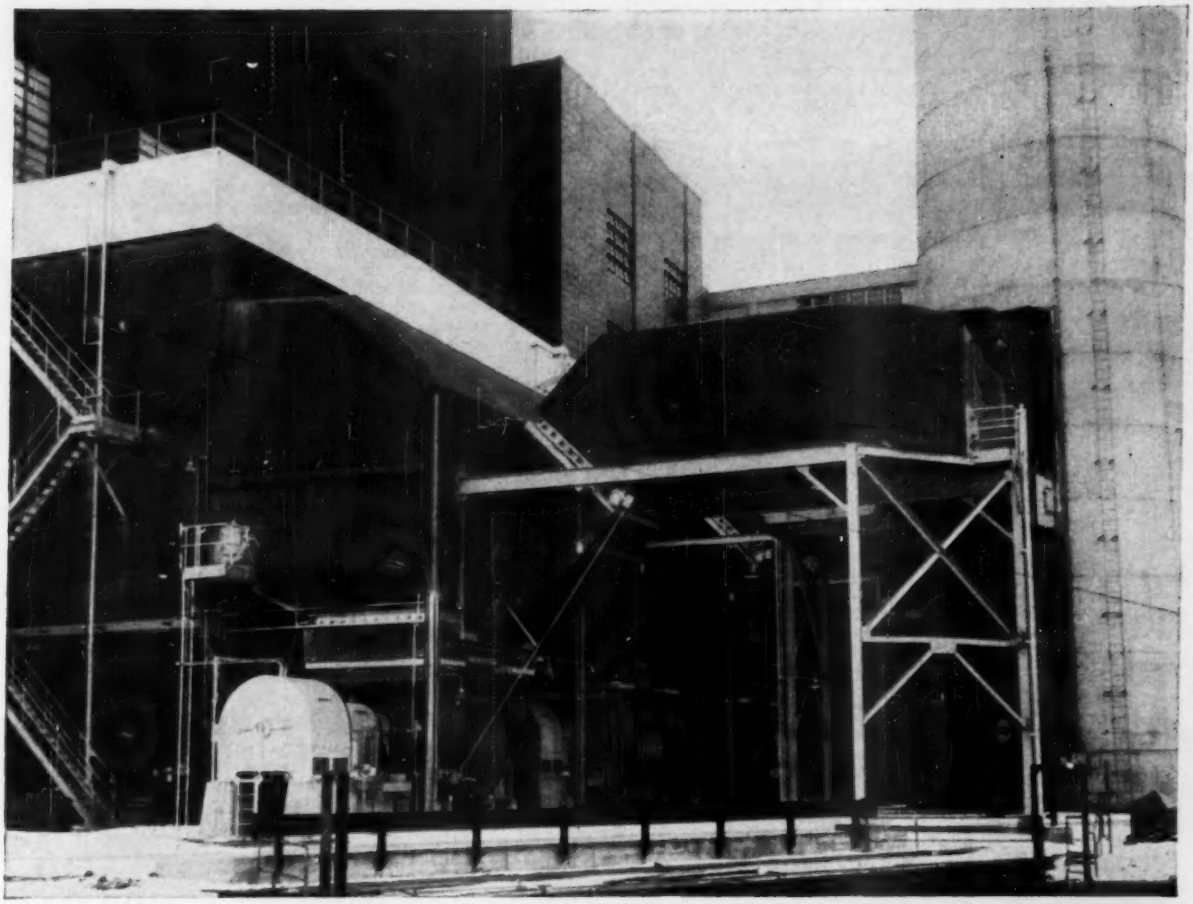
With Series 651 Gas Sampling Systems of Hays Corp. you design a system to suit your plant application using a "package" method of component selection. Component packages are divided into eight sections as follows: probes and accessories; steam regulators, sample filters and pressure reducers; ejectors; condensers, coolers and water separators; sample moisture separators and scrubbers; sampling flow regulators; water traps, bubblers and aspirators; multipoint sample valves. Not all eight sections are used on all applications — only those actually needed being provided. One of four basic methods of sampling is utilized in each system: steam ejector system; water operated gaspirator system; aspirator system, water or air; and pressure system. Publication 59-B651 gives specifications and instructions for selecting a system according to plant requirements.



6—STEPLESS DRIVE of simplified design

Engineered for a broad range of industrial applications, the low cost Kinatrol line of eddy-current coupling adjustable speed drives announced by General Electric Co. features simplified design, fewer moving parts. Longer service and reduced maintenance are claimed for the 5- to 100-hp units. This drive is a pre-wired





"Buffalo" Induced Draft Fans at Commonwealth Edison Company's Waukegan Station, Unit 7. Fans draw from a common precipitator plenum chamber and discharge into a common stack. Fans deliver 312,000 cfm at 21" S.P. at 300° F., have air cooled bearings. Engineered by Sargent and Lundy.

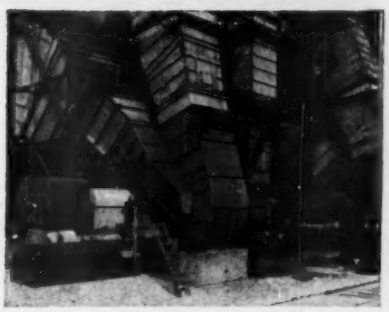
COMMONWEALTH EDISON COMPANY SELECTS "BUFFALO" FOR INDUCED DRAFT

The Commonwealth Edison Company has, over the years, purchased numerous "Buffalo" fans. This is a tribute to the performance, quality and long service life of "Buffalo" Products.

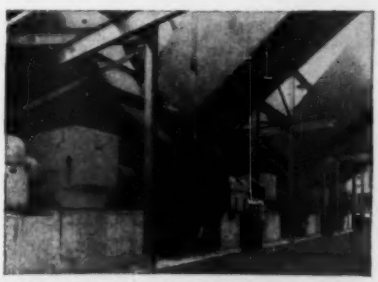
This same reliable performance and "Q" Factor Quality Construction is available to you in every "Buffalo" fan.

You are assured of getting the right fan for every job, too, since "Buffalo" offers a complete line of fan wheel types, each suited to a different set of circumstances.

The next time you need fans for any installation, large or small, be sure to phone your "Buffalo" Engineering Representative. He will have the best fan for the job and the experience necessary to see that it is recommended.



Installation photo, Commonwealth Edison Company's Will County Station Unit 3. This is one of four I. D. Fans now operating at 237,500 cfm at 15" S.P., 300° F. Engineered by Stone and Webster Engineering Corp.



Construction photo showing three of the four "Buffalo" I. D. fans at Commonwealth Edison Company's Fisk Street Station. These fans are now each operating at 362,300 cfm at 23.2" S.P., 325° F. Engineered by Bechtel Corp.

BUFFALO FORGE COMPANY
Buffalo, N. Y.
Buffalo Pumps Division Buffalo, N. Y.
Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

VENTILATING • AIR CLEANING • AIR TEMPERING • INDUCED DRAFT • EXHAUSTING
FORCED DRAFT • COOLING • HEATING • PRESSURE BLOWING

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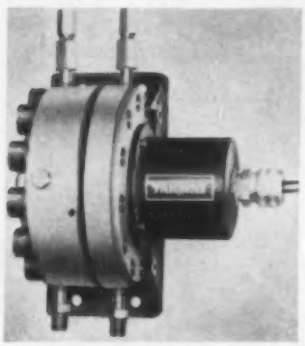
package including drive unit, control enclosure with control for both coupling and integrally-mounted Tri-Clad 55 a-c motor and operator station. Ratings through 20 hp are reported capable of continuous operation down to 100 rpm at rated torque providing a speed of approximately 17:1. Automatic control provides close speed regulation as standard, it is noted; on a typical friction type load, for example, regulation of 2 per cent of full speed can be obtained with standard equipment. Ratings are in horsepower delivered at output shaft of coupling. Publication GEC-1530 gives data.

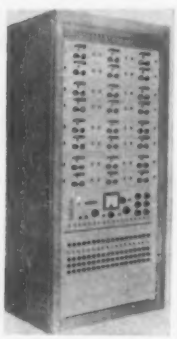
7—TRANSMITTER controls remote receiver

Success of the Yarway Remote Liquid Level Indicator has led to development by Yarnall-Waring Co. of a similar instrument operating without visual indication, and controlling a distant indicator, controller, or other electrically-operated receiving instrument. The new device — the Yarway Differential-Pressure Transmitter — consists of a diaphragm mechanism in a pressure housing with pressure connections at the bottom, and a sensing coil which operates the remote receiver. The transmitter can be mounted at any convenient location. It is connected to the liquid vessel, fluid line, or other container by two tubes. At the transmitter, the tube connections lead to opposite sides of the diaphragm. Variation in differential pressure on diaphragm causes change in output of sensing coil which is transmitted to receiver. Bulletin WG-1824.A gives details.



8—ELECTRONIC MULTIPLIER is versatile unit

MC-701 AM/FM Electronic Multiplier of Computer Systems, Inc., is designed to provide four quadrant multiplication, division or square root extraction of input variables at frequencies in excess of those feasible by other methods and with accuracy comparable to that of best low-frequency multipliers. It may also be used for interpolation and generation of functions of two or more variables. Flexibility in selection of operating mode makes the MC-701 a multipurpose computing component adaptable to sophisticated computing systems. No external amplifiers are required, and operational amplifiers provided as an integral part of the multiplier are available as inverters when the unit is not in use.



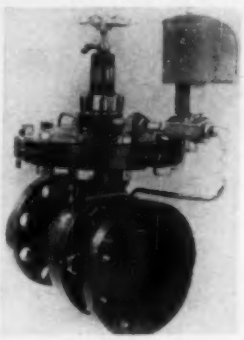
Improved performance is attributed to use of a new type of FM discriminator designed to overcome circuit detuning. The MC-701 may be furnished as an individual chassis for relay rack mounting or in groups of eight master and eight slave units in a console about 4 ft wide providing eight independent products and 16 dependent ones. Form 80-411-I gives data.

9—CHROMATOGRAPHY SYSTEM controls processes

Developed by Consolidated Electrodynamics Corp., and Taylor Instrument Companies, this continuous process control is a chromatograph-pneumatic combination. The control stores "peak" values from a standard process chromatograph and uses these as the basis for process control until the next peak value is supplied. This type of stream analyzer is designed to detect a deviation in final product purity and take self-corrective steps to bring the process back in line. The pneumatic controls include a potentiometer transducer to convert millivolt output of the chromatograph to pneumatic output and modified with memory storage to retain the value of selected peaks, and a pneumatic recorder-controller to record chromatograph peaks and to control by stroking a valve directly or resetting the control point of another controller that operates the valve.

10—REGULATORS provide off-on control

Solenoid-actuated regulators for on-off control are available from OPW-Jordan. They have application wherever remote shut-off, remote start up, automatic safety shut-off, and combination pressure and temperature control with an electric signal are needed. When the solenoid opens, it allows steam to enter the pilot chamber and operate the main valve as a normal pressure regulator. But when the solenoid closes, the steam supply to the pilot is shut off and the main valve closes automatically. The regulators come in ductile iron ½ to 3 in., bronze ½ to 2 in., and cast iron 2½ to 3 in.; they are suitable for temperatures to 500 F, pressures to 250 psi; come in screwed and flanged end models. Features announced include packless construction, silent operation, freedom from wire drawing. Details are provided in Bulletins SRBc 62–59 and JNP-1.



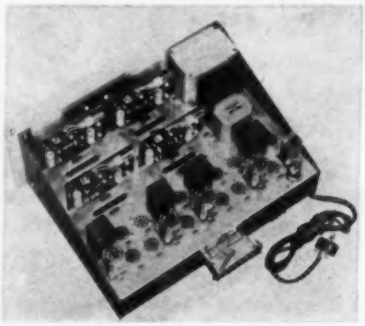
11—CONTROLS for pipeline automation

Consisting of three basic control panels, this "packaged automation" available from Clark Bros Co. ranges from a simple engine start system to a fully automatic engine and compressor control for remote location. With computer controller and telemetering equipment, any number of remote automatic panels can be tied together for automation of a complete station or pipeline. Instrumentation is matched to equipment it regulates, with control packages becoming more automatic and more complex according to functions automated.

Model SE (sequenced engine control) positioned adjacent to compressor, lets operator start or stop the engine with a single button. Functions are sequenced electrically. Model SEC (sequenced engine and compressor control) combines functions of engine and compressor control in one panel. Located at the compressor, it monitors and controls operating phases from start to stop. Illustrated is Model SEC-R (fully automatic, for remote location) has facilities for tie-in to computer control.

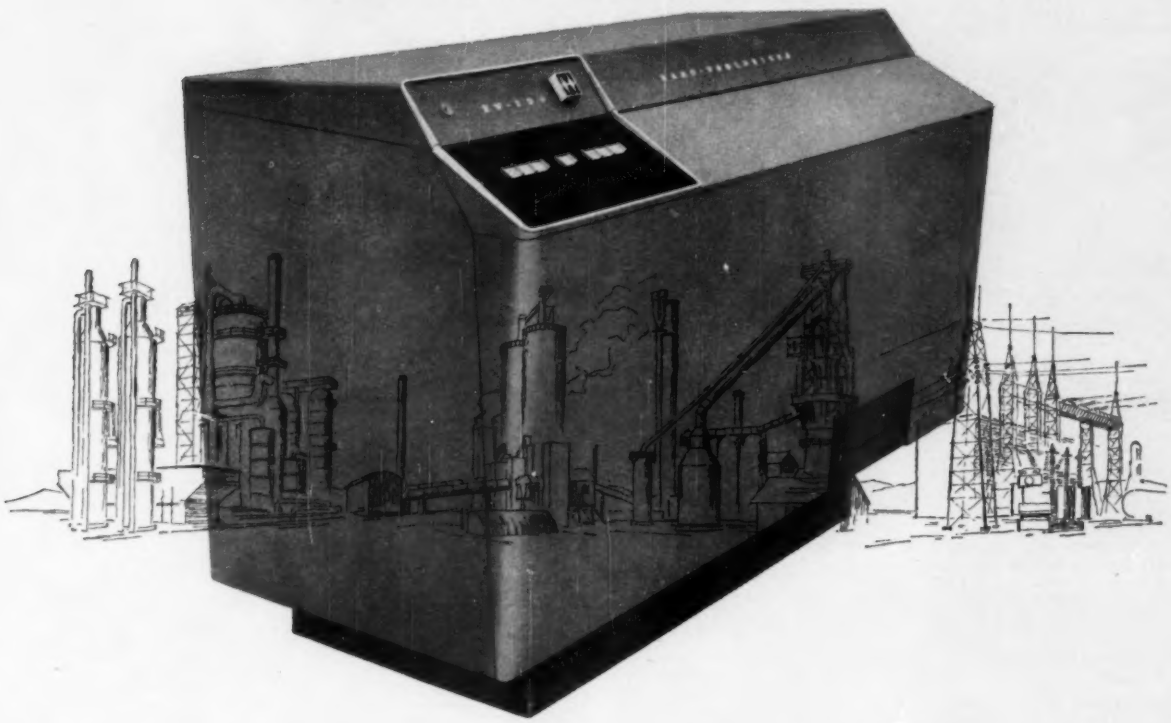
12—TELE SYSTEM uses existing phone lines

This transistorized telemetering system transmits on-off indications from remote stations to a central location, using existing telephone lines or other audio circuits. Produced by Dualex Div. of Bell & Gossett Co., this equipment enables operation of a remote station without personnel, as the system transmits to the central office an audio signal indicating equipment failure. Audio tones from 200 to 450 cps are used. Operation



In a Class by Itself

FOR CLOSED-LOOP CONTROL AND AUTOMATIC DATA REDUCTION



The RW-300

DIGITAL CONTROL COMPUTER

OPERATING SYSTEMS incorporating the RW-300 for on-line control and data reduction are demonstrating these tangible benefits: *reduced costs, increased output, improved quality.*

HIGH RELIABILITY, inherent in the advanced design of the RW-300, is being proven by thousands of hours of dependable operation.

SYSTEMS ENGINEERING staff, experienced in the analysis of complex control and data reduction problems, is assisting industry with applications of the RW-300 in chemical, petroleum, steel, cement, electric power, and other fields.

NATION-WIDE SERVICE organization is providing skilled maintenance for this completely developed, production engineered, and thoroughly tested piece of *industrial* equipment.

For further information, call or write Mr. Raymond E. Jacobson, Director of Marketing, The Thompson-Ramo-Wooldridge Products Company, 202 N. Canon Dr., Beverly Hills, Calif., BRadshaw 2-8892.

THE THOMPSON-RAMO-WOOLDRIDGE PRODUCTS COMPANY

a division of ***Thompson Ramo Wooldridge Inc.***

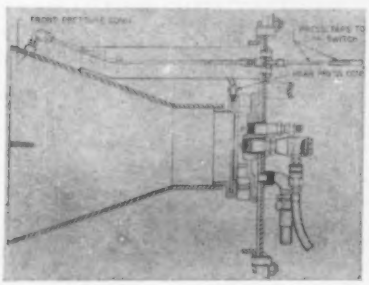
For more data circle 528 on Post Card

may be fail-safe (where normal condition is tone presence and loss of tone indicating off-normal) or vice-versa.

The basic system uses one to 10 telemetering modulators whose tone outputs are transmitted over the telephone line to a telemetering demodulator (shown). Up to 20 modulators and two demodulators may be used on a line. Interference with normal telephone use is prevented by a band-rejection filter supplied. An interline coupling filter is also available. If less than 10 channel capability is required in initial installation, the basic demodulator unit can be had with components for fewer channels. System capability can be increased with additional plug-in modules.

13—PILOT TORCH ignites main burners

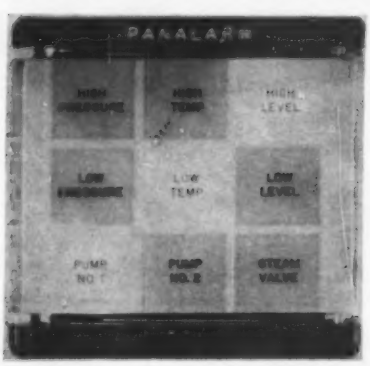
Designed to serve as an ignition torch for main oil and gas burners, the C-E Pilot Gas Torch, or Gas Side Ignitor, also serves to support ignition of pulverized coal burners. A development of Combustion Engineering, Inc., this is a spark ignited gas torch with flame indication, which can be operated locally from its control cabinet or remotely from control board. When operated remotely, usual practice is to operate one set of pilots, consisting of four torches at the same elevation, from one switch. If unit is of divided furnace or twin furnace design, one switch normally operates all pilots serving the coal nozzles supplied by the same mill or one elevation of oil or gas burners, in the same furnace. The differential pressure switch measures static pressure drop across the pilot torch nozzle. The drop increases appreciably when the torch is lit. This utilization of differential due to flame makes this unit one of the simplest of flame proving devices, it is noted. The differential switch is used to energize spark electrode to re-ignite pilot in event of flame failure. Indicating lights are energized by same switch.



More information on these products can be yours without cost or obligation. Use the postage-free Reader Service Cards provided for you on page 101.

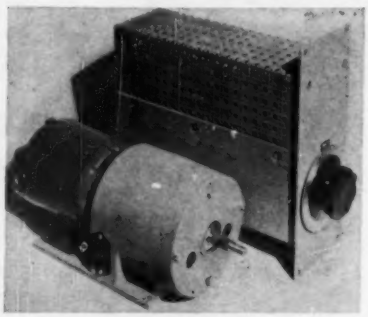
14—ANNUNCIATOR is economical, compact

The Panastat is announced by Panellit, Inc., as an economical, solid state, miniature, low-drain, expandable annunciator, providing information and control of industrial process systems. Decreased maintenance is claimed because there are no moving parts. Operational functions are performed by highly derated solid state elements. Low energy control circuits and negligible inductance provide intrinsic safety, it is pointed out, and ignition in hazardous atmospheres is impossible because no arc can be sustained. The Panastat operates on standard a-c or d-c line voltages, no transformer power supply being required. Continuous duty is maintained at ±20 per cent of nominal voltage, says company, and operation is not affected by normal line variations or surges. The miniature annunciator can be supplied to fit a 5-by-5 in., 6-by-6 in. standard instrument case or annunciator cabinet.



15— CONTROL offers accuracy and high torque

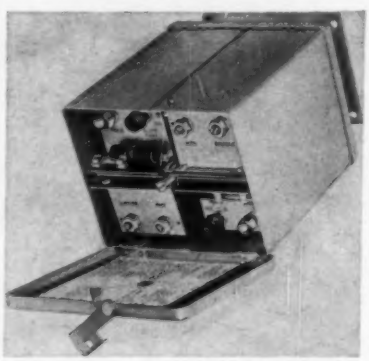
For industrial applications requiring fast response, high output torque, high accuracy, the economical 60-cycle Leartron Positioning System of Lear, Inc., is a closed-loop remote positioner. Units consist of a combined controller-amplifier and a servo drive. The controller converts movement of a manual control (dial, lever, pre-set pushbutton) into an electrical error signal. The amplifier discriminates polarity of the signal and transmits a current (proportional to error signal) to one of the two magnetic powder clutches in the servo drive, which rotates the output shaft in the commanded direction. Exceptional loop stability is said to result from the clutch current feedback network and a balanced gear train which eliminates backlash.



The output shaft, driven by the high-response powder clutch, follows movement of the manual control. At maximum excitation, servo output torque is 250 in. lb. Installation is simplified by modular construction, permitting the control to be panel-mounted away from the amplifier and the servo gearbox to be separated from the drive for a "gang" hookup.

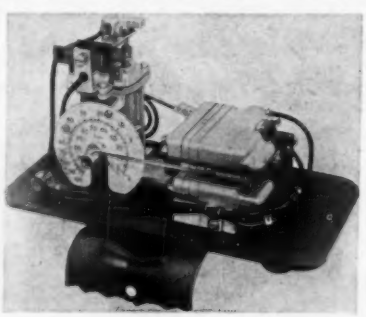
16—ALARM with built-in power supply

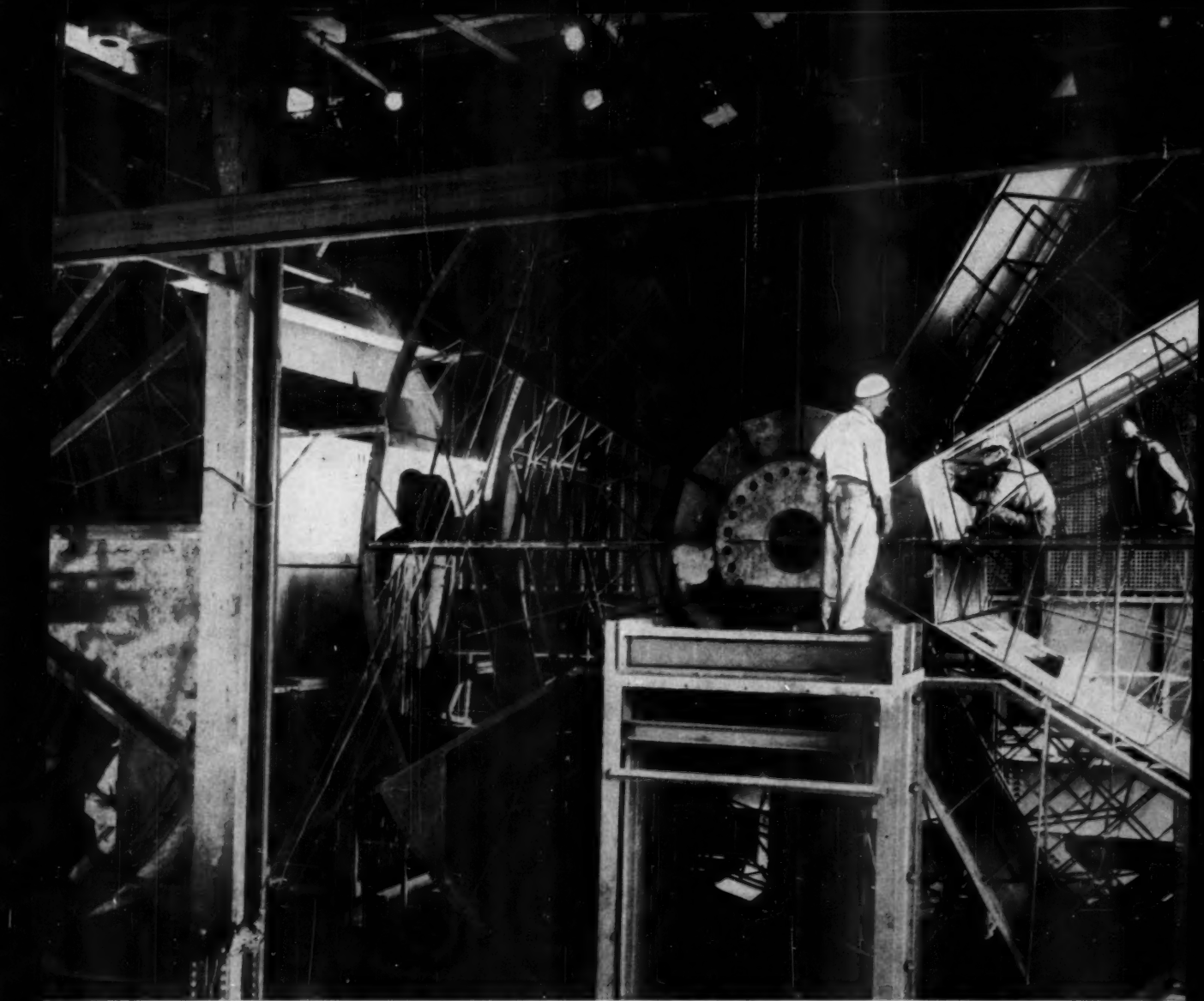
The R2A Electronic Alarm of Swartwout Co. can actuate an annunciator or perform an auxiliary control function when a process signal reaches a preset point. Though equipped with built-in power supply and adjustable alarm-point signal, unit can be installed with alarm-point set from a remote location. It is a null-balance device for one- or two-point alarm, operating independently of the instrument's circuit or in parallel with an AutroniC indicator-recorder-controller combination. Basic components for a single alarm-point are mounted on two printed circuit cards. Each unit has slots for two sets of these, permitting both high and low limit alarms. The alarm is comprised of a plug-in case, containing the printed circuit cards, and a mounting frame. Operating from a common 0–0.5 v a-c signal, the R2A compares process signal with adjustable alarm-point signal in a difference amplifier. More information is in Specification Sheet A809.



17—FUNCTION GENERATOR for flow readout

The Function Generator introduced by Taylor Instrument Companies converts a pneumatic input signal into a characterized output. Its principal use is in linearizing the signal from a differential pressure type flow transmitter to assure faster, more accurate readout on linear scales and charts. This instrument also offers optional interchangeable cams which perform an unlimited variety of functions other





Two of the four Ljungstrom Air Preheaters under construction at Potomac Electric Power Co.'s Dickerson Power Plant, Dickerson, Md. Each pair of these Ljungstroms, with a combined heat exchange surface of 475,000 sq. ft., will serve one boiler, evaporating 1,300,000 lbs of steam/hr. The first 175,000 KW unit was placed in operation in June this year and a duplicate unit is now under construction.

AIR PREHEATER SERVICE

PROTECTS POTOMAC ELECTRIC POWER CO.'s NEW **LJUNGSTROMS®** TWO WAYS

From the moment they start—and for as long as they operate—these Ljungstroms will get double-header Air Preheater service: protection against routine wear, and insurance of maximum operating efficiency. This is how.

Lifetime Air Preheater Service provides regular inspection and the services of expert technicians throughout the life of each unit. Air Preheater engineers make personal calls at least once a year on every Ljungstrom installation to make sure that all units are in top condition. This type of service is still in effect on Air Preheaters dating from 1923.

Rapid factory service gives the best possible protection against routine wear, the best insurance of readily-available replacement parts. In one typical case, an Air Preheater customer 500 miles from the factory received *custom-fabricated* parts within ten hours after his initial request for these parts.

Regular inspection and fast response to emergencies are just two advantages Air Preheater offers its customers. Another is expert knowledge of boiler and preheater problems, gained through 35 years' experience. These reasons—knowledge of our customers' problems and a *continuing* interest in them—probably explain why nine out of ten preheaters sold today are Ljungstroms.

THE AIR PREHEATER CORPORATION

60 East 42nd Street, New York 17, N. Y.

For more data circle 529 on Post Card

than linearization of flow measurement. Applications include measurement and control of feedwater or steam flow in power production; ratioing of flow involving viscous liquids, slurries, suspensions or liquids that "jell" when not in motion; cascade control systems involving flow and a linear variable measurement; and totalizing measured variables.

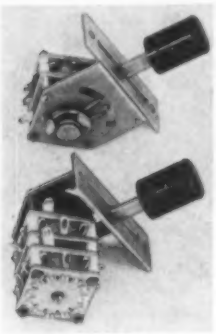
The Function Generator permits standardization on linear scale and charts for all variable measurement, it is pointed out. It utilizes a 3–15 input signal from a transmitter and produces a high capacity linearized 3 to 15 psi output signal to a receiver and/or controller. Bulletin 98369 gives details.

18—OVERLOAD DETECTOR for water clarifiers

Protecta-Trol, an overload indicator and controller for water clarification units, developed by Graver Water Conditioning Co., registers sludge overload on an indicator and has contacts for alarm or light signals and for shutdown of the unit. It is regular equipment on company's high-rate, solids-contact clarifiers and softeners, and horizontal flow gravity separators. Protecta-Trol is housed in a galvanized iron assembly. It works off the input worm of the speed reducer which is spring loaded so that any increase in load above a preset point causes the worm shaft to compress the spring and allows the shaft to move. The moving shaft actuates a sensing plunger which causes movement of a pointer on a scale. The plunger, by making direct mechanical contact with the drive mechanism, produces an actual torque reading.

19—LEVER-ACTUATED SWITCH for panel mounting

Type MA-12, a miniature switch announced by Electro Switch Corp., is designed to provide multi-circuit control, panel mounting, and lever operation in a compact unit suitable for low-power and electronic circuits. The assembly can be had with one or two sections, giving up to 12-pole switching. The lever actuator can be arranged to be spring-returned to center from either or both of the two end positions or can be maintained in any or all of the three positions, or limited to two. Electrical ratings are 3 amp continuous current at 115 v a-c; interrupting rating, ½ amp at 115 v a-c; voltage breakdown 1000 v rms. Current carrying parts are silver-alloy material. A "flying arm and star wheel" detent mechanism affords non-hanging positioning.



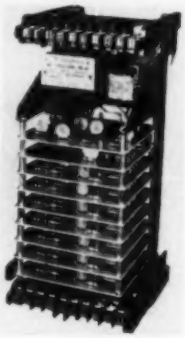
20—CONTROL UNIT with float-probe actuation

Model EA100P is a recent addition to The Reliance Gauge Column Co.'s line of Levalarms — control devices for operating high and/or low water level alarms, cutting off fuel, and controlling feedwater pumps, automatically and in response to changes in boiler water level. Levalarms are of two basic types: float actuated and probe actuated. Model EA100P employs both float and probe actuation means within a single chamber and is designed to comply with insurance association codes requiring two independent fuel cutout devices to be installed on package boilers. Having both independent and different fuel cutout actuation means in a common chamber affords economy not only in purchase price, but of piping installation and electrical interwiring costs as well. Utility of this Levalarm is enhanced by provision of a second probe that will operate a low water alarm signal, if desired, above the fuel cutout actuation level.

21—TOTALIZING RELAYS for multi-unit metering

Impulse totalizing relays announced by Westinghouse Electric Corp. for multi-unit metering of power distribution systems use semiconductor devices to combine demand impulses from as many as seven sources and to retransmit them over a single output circuit. With the exception of one output relay, circuit elements are conservatively rated static devices — transistors, silicon diodes, condensers and resistors — which operate at high impulse rates for long periods.

The equipment is reported compatible with existing systems without changes in input pulsing equipment or final impulse receiver. Available with capacities of three, five or seven input channels, the new relays have a common maximum output rate of 450 impulses per minute, but a maximum input rate depending on number of input channels to be totalized. All three units are available in output-impulse to input-impulse ratios of 1:1, 2:1 or 4:1. Input impulses to be totalized can originate from any three-wire contact device or equivalent relay, whose output consists of one closure of each side of the three-wire circuit. Unit mounts in a standard relay case.

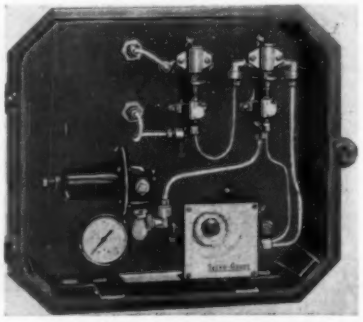


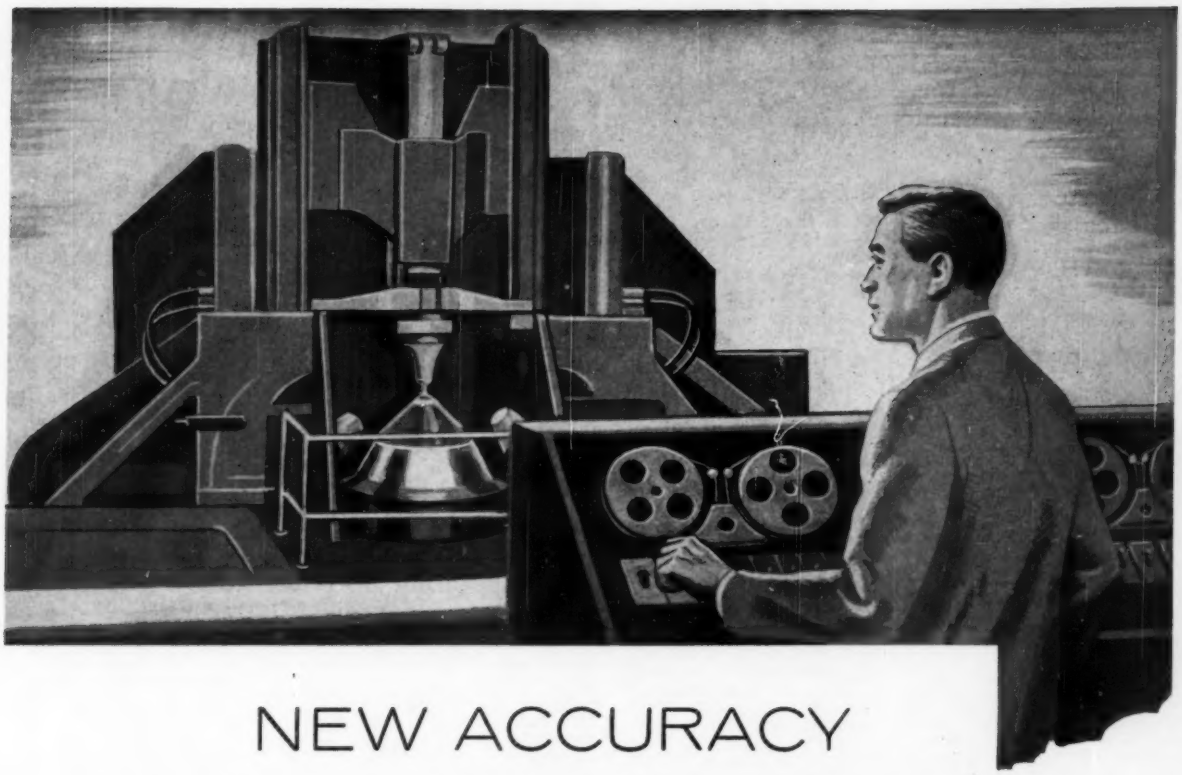
22—TEMP CONTROL for operation to 2000 F

Essentially a temperature transmitter, Model OA, of Burling Instrument Co., is designed to provide air pressure proportional to temperature and is used for direct operation of air operated diaphragm valves, motors, dampers. Distinguishing features announced for this pneumatic temperature control are: differential expansion actuating tube permitting operation from sub-zero to 2000 F; weather- and dust-tight cast aluminum housing; choice of mounting fittings; use of simple bleed type pilot valve. Installation is by inserting tube assembly (shown at bottom) in heated space. Air connections are made to fittings shown at top. Bulletin 152 gives details.

23—TIMER is pneumatically actuated unit

The Servo-Gauge Oscillator is a pneumatically actuated timer without moving parts or linkages. According to manufacturer, Associated Control Equipment, Inc., it is ideal for explosive hazard areas, remote locations, and services requiring repeated accuracy of response. The timer sends out, on a predetermined time cycle, a repetitive signal impulse of a preset magnitude, or of a variable magnitude if initiated by a controller.





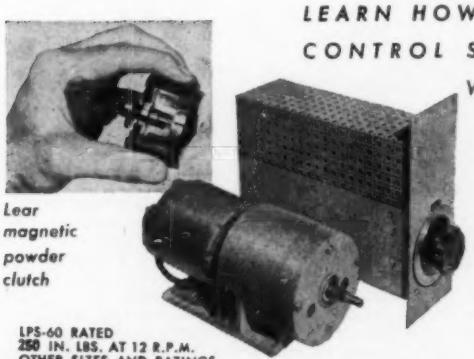
NEW ACCURACY

for industrial remote control

LEARTRON 60

Extreme accuracy — within ¼ degree • High frequency response — three times greater than obtained with conventional electrical equipment • Self-contained — simple and easy to install, operate and maintain • Complete versatility — readily adaptable to all phases of industry • Operates on 115 V, 60 cycle power.

MACHINE TOOLS
MATERIAL HANDLING
CONTROL MODULATION
PACKAGING
TESTING
HAZARDOUS PROCESSES
SPEED CONTROL
FLUID TRANSMISSION



Lear magnetic powder clutch

LPS-60 RATED
250 IN. LBS. AT 12 R.P.M.
OTHER SIZES AND RATINGS AVAILABLE

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ELECTRO-MECHANICAL DIVISION

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For more data circle 530 on Post Card

Signaling impulse frequency, variable from 0.3 to 60 cycles per minute, is adjustable within the instrument case. Amplitude of the output pressure can be adjusted manually at the instrument or at a remote control center, or automatically by a pneumatic transmitter. Output signal is essentially a rectangular pressure wave having an amplitude of any pressure in the range from zero to 30 psig. Applications include speed control of diaphragm pumps, on-off control of cylinder or diaphragm operated valves, timing actuation of power cylinders, timing alternator of fluid transfer systems, etc. Actuating power is a source of clean air or non-corrosive gas at 30 psig or as available.

24—OPERATIONS RECORDER is economical unit

As announced by Fischer & Porter Co., the transistorized MOR (milleseconds operations recorder) is a simple method of recording important station operations automatically at less than a third the cost of many methods, although offering accuracy and reliability, flexibility and low maintenance. It simplifies analysis by recording every change in trouble contact position, establishing time and sequence events occurring within milleseconds of each other. MOR is also suggested for checking pre-run operation of drop-out relays and other protective devices. It can remotely monitor far flung substations; it can be treated as a portable instrument.

Every trouble contact is wired to a point coding assembly, one of 10 on every plug-in tray. Trouble contacts can be any which reflect on or off states. When a contact opens or closes, it energizes its associated point coding assembly, which responds by sending out an electronic "number" and an "on" signal, if that is the direction of the event. Identifying point number and "on" are printed. Tape is set in motion. Timing track is imprinted once each cycle. Tape runs for 12 cycles and stops. Catalog 30A1400 gives full details.

Use the Reader Service Cards on page 101 to get further information on any of these developments.

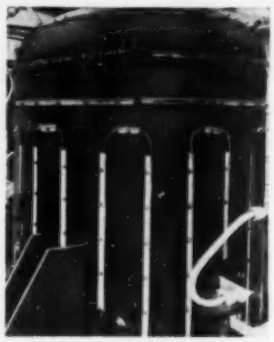
25—LOADING COMPUTER is low cost programmer

BELAC is a load distribution analog computer developed by Belock Instrument Corp. for instant visual interpretation of operating data in power systems. It is said to cost up to 50 per cent less than conventional apparatus performing the same function, and is housed in a portable cabinet convenient for desktop use. According to manufacturer, this economy analog is adaptable for custom programming and helps reduce fuel and maintenance costs by furnishing information on most efficient load distribution among many generators.

Information fed to computer by adjustment of control knobs includes fuel cost, maximum and minimum capabilities of individual generators in a system, base load generation, interchange sales system total. Provision is also made for future insertion of effect of line losses on economy loading computations. System conditions are continuously variable over entire range, it is noted, and any given machine can be switched into or out of computation at will. Among factors dealt with are turbine back pressure, spinning reserve data, cooling water temperature limitation.

26—STRIP DETECTOR warns of overheat danger

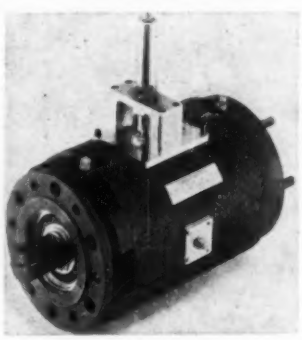
For early warning of overheat conditions, the continuous strip detection system of Walter Kidde & Co., Inc., utilizes strips up to 20 ft long coupled together to form longer strands. Of flexible Inconel tubing containing two wires imbedded in a ceramic, thermistor core, the strip is attached to the surface of equipment to be protected with spacing of strands and patterns subject to degree of overheat coverage desired and shape of equipment involved.



Normally a voltage not over 10 v is applied to the circuit. At normal operating temperatures, the ceramic offers high resistance to flow of current between the two conductors. When subjected to temperatures above this point, resistance of the ceramic drops and permits an increased flow of current between the two wires. When a predetermined resistance is reached, the monitoring control unit causes an alarm to sound. The strip detectors have an alarm range of 200 to 1000 F, but can be subjected to temperatures down to −65 F. While normally used for overheat detection only, they can be adapted for detection of temperatures above and/or below normal.

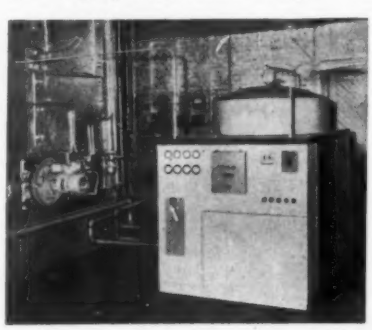
27—ASSEMBLY measures torque in rotating systems

As announced by B & F Instruments, Inc., this torque shaft assembly is a measuring instrument involving both electrical means for measuring a torsional strain and mechanical assembly for providing that strain. This assembly, equipped with high speed bearings and suitably housed, comprises the standard Torquometer. Variable inductance transducers measure angular twist in torque shaft which is proportional to torque. This signal is fed through a low-noise slip ring and brush assembly and output read on standard carrier amplifier equipment or suitable indicating system. Standard ranges are 1 to 30,000 in.-lb full scale; speeds, to approximately 50,000 rpm. Bulletins TM and TM-400C give data.



28—CONTROL SYSTEM keeps boiler water clear

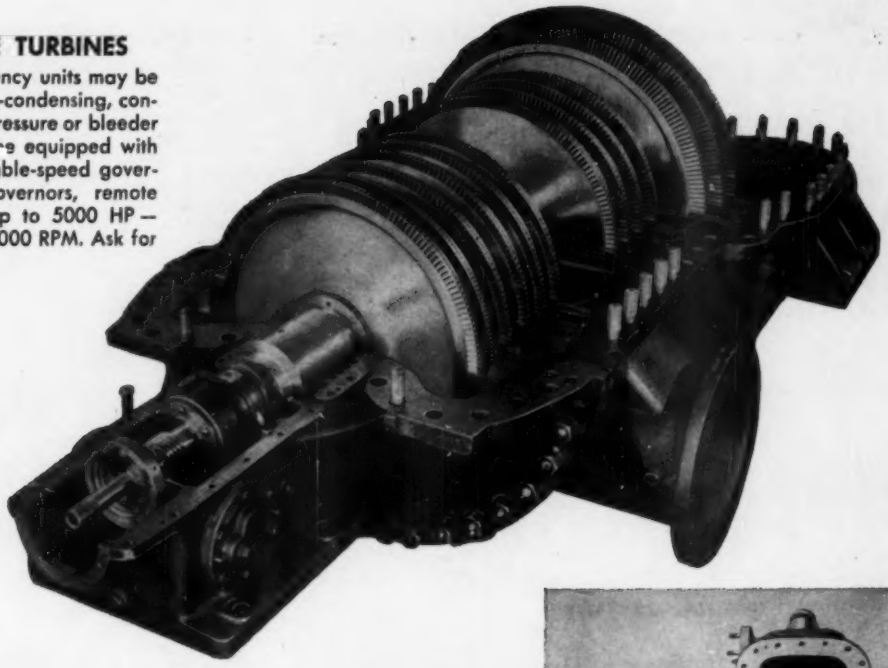
Filtrion Automatic Side-Stream Boiler Water Control, produced by Sparkler-Filtrion Corp., is designed to keep boiler water clear by eliminating sludge and suspended solids. Worthwhile savings in treatment chemicals, blowdown heat and water losses, fuel consumption are reported along with reduced operating costs — with savings on contaminated condensate losses ranging up to 100 per cent. Standardized models are available for all types of boilers to 1000 hp, customized units for those to 6000 hp.



The system is based on continuously recirculating boiler water through a side-stream filter pre-coat that reduces suspended solids to a value close to zero. These units also combine side-stream filtration with chemical pretreatment, internal

MULTI-STAGE TURBINES

These high-efficiency units may be designed for non-condensing, condensing, mixed pressure or bleeder operation. Can be equipped with constant or variable-speed governors, special governors, remote controls. Sizes up to 5000 HP — Speeds up to 10,000 RPM. Ask for Bulletin S-146.



There's a **Terry turbine** for every mechanical-drive requirement

The designs for Terry turbines are based on more than 50 years of successful experience in the manufacture of turbine drives *exclusively*. This specialization has resulted in Terry becoming one of *the leading producers* of mechanical-drive turbines in sizes up to 5,000 horsepower.

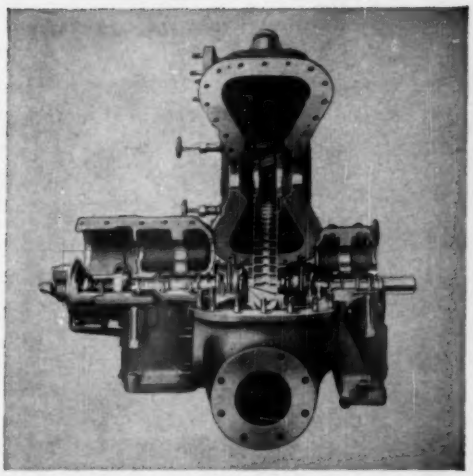
There are three basic reasons why Terry has been able to maintain this position of leadership: (1) a thorough knowledge of the requirements of mechanical-drive turbines, (2) a willingness to build "a little something extra" into each machine to assure trouble-free operation, and (3) an acknowledgement of the company's responsibility to stand behind the performance of every turbine sold.

These are also the reasons why you should consider a Terry turbine for your next mechanical drive. In the meantime, send for bulletins describing any of the types of machines illustrated.

THE TERRY STEAM TURBINE COMPANY
TERRY SQUARE, HARTFORD 1, CONN.

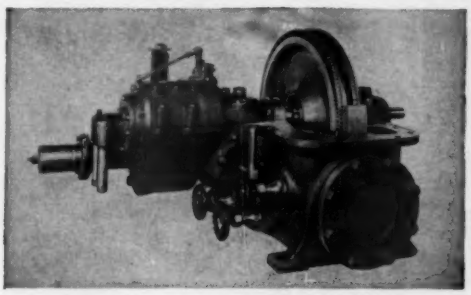
TERRY

TT-1209



SOLID-WHEEL TURBINES

Famous for sure dependability and ease of inspection. Can be started cold — no preliminary warming required. Available in vertical designs depending on frame size. Capacities from 5 to 2,000 HP. Described in Bulletin S-116.



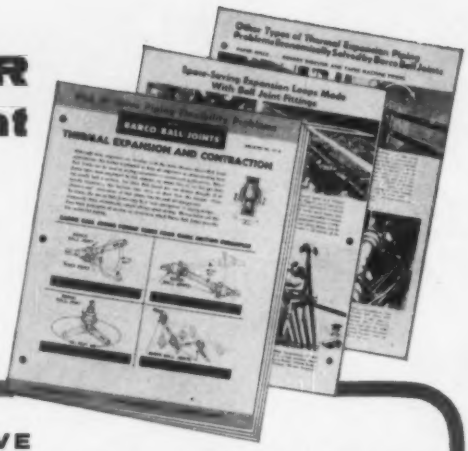
AXIAL-FLOW IMPULSE TURBINES

Built with one, two or three rows of high-grade stainless steel blading, these turbines combine efficiency with durability. Available in designs for moderate and high steam pressure. Bulletin S-143.

For more data circle 531 on Post Card

EVERY ENGINEER will want these FACTS!

NEW EDITION
Bulletin No. 31-A



"HOW TO SOLVE

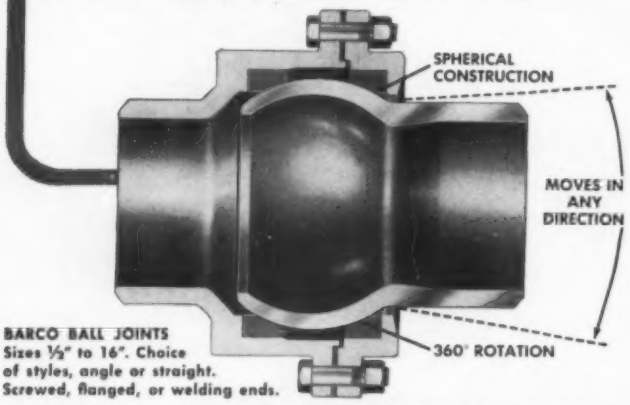
PIPE EXPANSION

PROBLEMS"

TODAY there is an easier way to accommodate *thermal expansion* in piping! No need to install special devices—in virtually every instance, you can put *flexibility* right in the line itself with standard BARCO BALL JOINTS:

1. **SUPERIOR METHOD.** New Steam Power Stations . . . Oil Refineries . . . Chemical Plants . . . Paper Mills . . . Office Buildings . . . Schools now are using this money-saving method.
2. **LONG LIFE.** No rubber, no thin metal members subject to fatigue or "blow-out." No lubrication, no grease packing. Self-adjusting; pressure sealing.
3. **FIRE-SAFE.** The joints have passed rigid fire, high temperature, and water quench tests.
4. **SAVE SPACE, CUT COSTS.** No pressure thrust—expensive anchoring or bracing not required to hold piping in place or in line. Cuts space required for pipe loops and U-bends.
5. **VERSATILE.** Easy to handle compound twisting movements, wide variations in temperature and pressure—steam, air, oil, water, gas and chemicals.

SEE your Barco Representative for information or write. Ask for the new revised Bulletin No. 31-A, "How to Solve Piping Flexibility Problems." *Engineering recommendations on request.*



BARCO BALL JOINTS
Sizes ½" to 16". Choice of styles, angle or straight. Screwed, flanged, or welding ends.

PRODUCTS BACKED BY EXPERIENCE
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The Only Truly Complete Line of Flexible Ball, Swivel, Swing and Revolving Joints
In Canada: The Holden Co., Ltd., Montreal

For more data circle 532 on Post Card

treatment, continuous minimum blowdown and feedwater preheating and degassing, and are fully automated.

29—WARNING SWITCH can operate in any fluid

This explosion-proof, hermetically sealed, low- (or high) level warning switch is designed by Acme Machine Works for use in almost any liquid. According to

manufacturer, switch cannot be affected by contaminants in fluid, or by rolling or pitching motions. It can be installed to warning lights and/or automatic switching mechanisms to start pumps or open auxiliary lines. A time lag mechanism is provided to prevent tripping even when upside down for less than 3 sec. The switch weighs less than 16 oz, operates on any electrical system from flashlight battery to 300 v at 5 amp, temperature from −65 to 250 F.

30—BIN LEVEL INDICATOR is designed to resist corrosion

Auto-Bin-Dicator is announced by the Bin-Dicator Co. as a supersentive response mechanism for use with light materials without affecting its performance with heavy materials or for general purposes. Standard and explosion-proof models are available. For corrosion resistance, the body is heavy aluminum castings and diaphragm is stainless steel. Unit can be affixed to thick or thin walled bins, or suspended within bin at any level with a simple extension. It can also be used in chutes and hoppers to prevent overfeeding. In operation, pressure of material against diaphragm actuates a switch which operates signals, such as lights, bells or horns, and can be set to automatically start or stop material flow into or out of bin and stop or start filling machinery.

31—FEEDER SYSTEM treats air conditioning cooling water

For continuous, automatic proportioning of liquid chemicals in treating cooling tower water, the Automatic Micro Feeder of The Bird Archer Co. is designed to eliminate daily charging. It supplies $\frac{1}{10}$ of 1 gal of filtered liquid chemical into the circulating water every 24 hr. One or two 55-gal drums of chemical will last a season under normal conditions, according to Bird Archer. Heart of the equipment is an aspirator type chemical feeder with a differential pressure regulator maintaining a constant pressure drop across a porous stone that acts as a rate valve. The feeder is connected to suction and dis-

Solar Field Engineer Bill Emery inspects a Sola-Flex joint in the Los Angeles Department of Water and Power's Valley Steam Plant

JOINT EXPERT

Solar's experienced staff of field service engineers is ready to help solve your difficult expansion joint problems

THIS SIX INCH Sola-Flex® joint—being inspected by one of Solar's experienced field service engineers—is one of twenty-four such joints in a fuel gas piping system at the Los Angeles Valley Steam Plant. Together, the joints have handled 2 million cu ft of gas per hour—*for the past five years!*

Wherever you are located in the United States there is a trained Sola-Flex field engineer nearby, ready to help you achieve dependable results with your expansion joint installations. This prompt, efficient service is but one of the reasons why forty of America's fifty largest businesses rely on Sola-Flex expansion joints.

Solar manufactures the most comprehensive line of expansion joints in the world. They are made from a wide variety of stainless and high alloys for important nuclear, missile and industrial applications. Write today for details to Dept. G-166, Solar Aircraft Company, San Diego 12, California.

SOLAR
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ENGINEERS WANTED! *Challenging projects, unlimited opportunities with Solar. Write today!*

For more data circle 533 on Post Card

easy way to keep tubular equipment good as new

Airetool tubular maintenance tools give work crews everything they need to clean boiler condenser and heat exchanger tubes faster, more efficiently. These tools are designed with plenty of power to get the job done right — in a hurry.

The lightweight Model CC-475 Airetool condenser and heat exchanger tube cleaner drives cleaning heads through hardest deposits without stalling . . . at the same time, a built-in flushing system washes out debris. Yet this hard-working tool weighs only 10 pounds — one man handles it easily without a supporting rig. And, when it comes to retubing bundles, Airetrol, automatic tube expansion control can't be beat. It easily rolls up to twelve ¼" to 1½" tubes per minute.

For cleaning large diameter curved tubes Airetool air-driven cleaner head motors produce high speeds and extra power for heavy duty performance. Motors maintain speed and power even when the most severe deposits are encountered.

For complete information about these time and money-saving Airetool tube maintenance tools that keep condenser and heat exchanger tubes operating at like-new efficiency, write for Bulletin No. 66.

30 years experience in pneumatic tools

BRANCH OFFICES: New York, Chicago, Tulsa, Philadelphia, Houston, Baton Rouge
REPRESENTATIVES in principal cities of U.S.A., Canada, Mexico, South America, England, Europe, Puerto Rico, Italy, Japan, Hawaii
CANADIAN PLANT: 37 Spalding Drive, Brantford, Ontario
EUROPEAN PLANT: Vlaardingen, The Netherlands

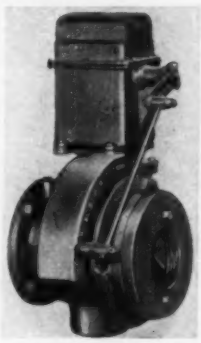
AIRETOOL
MANUFACTURING COMPANY
SPRINGFIELD, OHIO

For more data circle 534 on Post Card

charge lines of the cooling tower water circulating pump. Differential pressure, averaging 20 to 40 lb, creates a vacuum in the reagent side of the unit that induces reagent flow from the supply drum into the container through the porous stone and the differential pressure regulator and then into the main stream at the aspirator. The unit is for cooling towers of 10- to 400-ton capacity in normal operation.

32—PROPORTIONING VALVE for manual or automatic operation

Available in five sizes, Eclipse Fuel Engineering Co.'s Varitrols are designed with an economical two-in-one valve method of controlling air and gas to provide blending required for any firing condition. According to manufacturer, the Varitrol not only permits proper



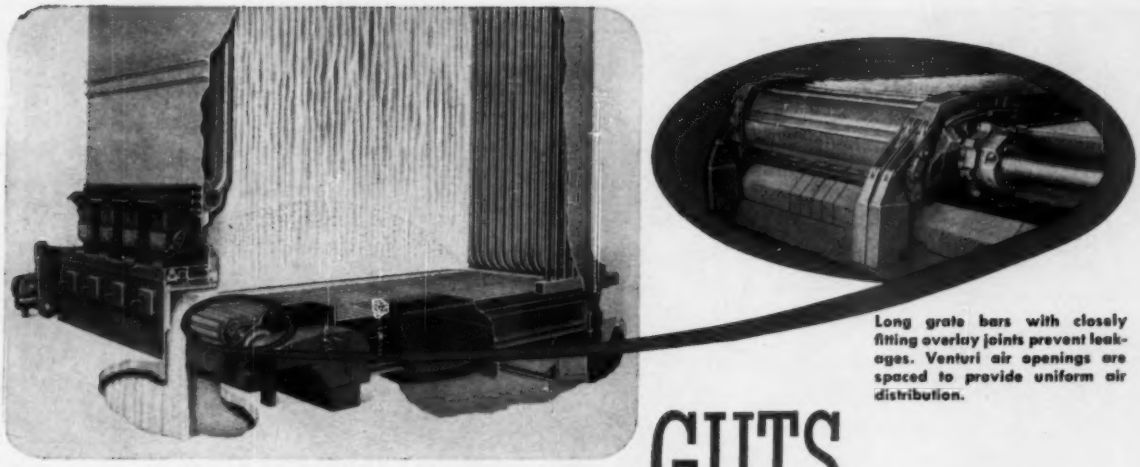
setting for firing condition without trial-and-error adjustments, but also assures repeatability. Returning control arm to any position, manually or automatically, assures an air-gas mixture identical with previous settings, it is stated, and because Varitrols have nine gas-adjusting screws, the air-fuel ratio may be adjusted for each valve position. Electric or air-operated automatic controls may be used. Varitrols can be used to handle manufactured or natural gas, propane, butane, and can be used to supply multiple burner installations.

33—ANALYZER for the lower levels of dissolved oxygen

Especially designed for the power field by Industrial Instruments, Inc., this instrument utilizes a unique property of metallic thallium which is extremely reactive to traces of oxygen in water — while being inert to water itself. The reaction product is soluble thallous hydroxide which increases the conductivity of water. Each ppm of dissolved oxygen on complete conversion to thallous hydroxide increases specific conductance of pure water by close to 35 micromhos/cm at 25 C. For low concentration of oxygen in the ppb range, sensitivity of the method is increased by demineralizing the water sample to decrease the background conductivity.

The instrument consists of a mixed bed demineralizer cartridge and packed column of pure thallium. Water conductivity is measured before and after passage through the thallium column. Conductivity difference is directly related to dissolved oxygen content of the water. Bulletin 16034D gives details.

Equipment for Automation continues on page 101.



Long grate bars with closely fitting overlay joints prevent leakages. Venturi air openings are spaced to provide uniform air distribution.

GRATES ARE THE GUTS OF A STOKER ——— DETROIT ROTOGRATE HAS PLENTY OF INTESTINAL FORTITUDE

No matter what else it has, no stoker can be a complete success without trouble free efficient grates.

The Detroit RotoGrate Stoker has other outstanding features in abundance but without the superior grate design it could never have achieved such instant and lasting success.

The advent of the RotoGrate Stoker established a whole new trend in coal firing and stimulated many competitors but none has seriously challenged the superior performance and long life of the RotoGrate.

Our grates are high resistance metering type with venturi air openings spaced to provide uniform air distribution. Long grate bars have close fitting overlay joints to prevent leakages that cause blow holes and burnouts.

Sturdy construction and use of special alloy iron makes these grates long lasting under the most exacting service.

Guide chains riding over toothed sprockets assure positive grate bar alignment. A unique method of attachment avoids chain wear and stretching, while the catenary take up of slack prevents jamming.

Forward travel continuously discharges ash. Automatic combustion control varies the speed of travel in step with fuel feed rate to maintain uniform fuel bed while following fluctuations in load.

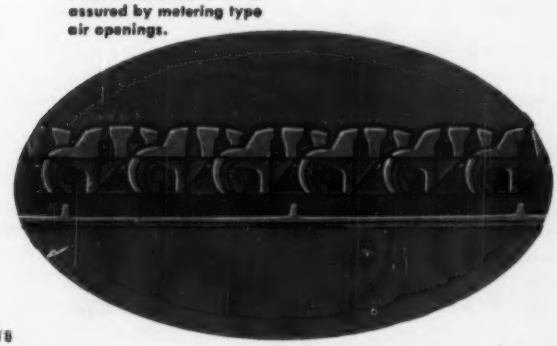
Burns all grades of bituminous and lignite coals, also many kinds of refuse and by-product wastes.

The RotoGrate for boilers to 400,000 pounds steam per hour capacity; other Detroit Stokers for capacities from 3,000 pounds steam per hour.

DETROIT STOKERS COST LESS

Cost equals initial investment plus upkeep plus production losses due to equipment outage. The total is less with Detroit.

Even distribution of air is assured by metering type air openings.



DETROIT SINCE 1898 STOKERS

DETROIT STOKER COMPANY

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District Offices or Representatives in Principal Cities

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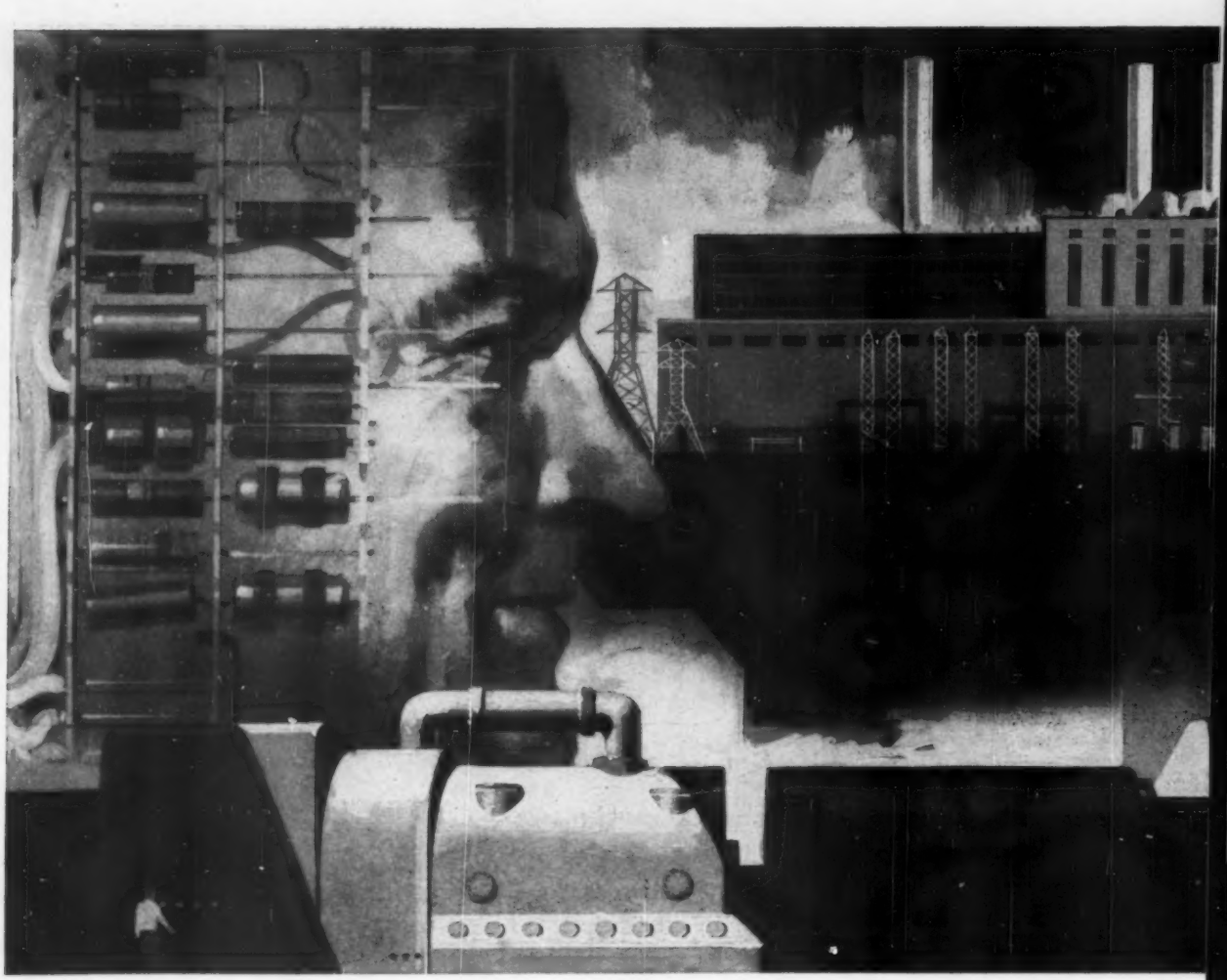


Westinghouse PRODAC computer-controlled system operates your power plant automatically

Integrates all station controls to increase efficiency, reliability, to decrease operating costs, risks of emergency decisions

The completely automatic power plant is a reality with Westinghouse PRODAC® . . . the system of *PRO*grammed *D*igital *A*utomatic *C*ontrol utilizing an advanced control computer.

The Westinghouse Prodac digital control computer is designed specifically for control systems, with a logic unit and priority director to simplify and expedite making the "thousands of decisions" needed in sequencing and control of a power plant; and to change the sequences automatically whenever needed to start up, shut down, or run the plant at maximum efficiency under normal and emergency conditions.

The Prodac system not only scans and logs system quantities, but through extensive calculations presents them directly in more meaningful terms of heat rates and unit efficiencies. By analyzing these, it can make required changes in controlled quantities to optimize performance of the entire plant.

®Trade-Mark

Prodac ties together other control subsystems such as generator hydrogen control, automatic turning gear, turbine starting speed control, with combustion, feedwater and superheat control.

Above all else, the Prodac system design stresses reliability. In the design of the computer, its application and integration with auxiliary controls, the focus of all engineering considerations is to provide the most complete, most reliable control of the turbine-generator, the boiler and all auxiliaries.

Westinghouse will design and build the complete control system. Westinghouse will, in addition, coordinate the total plant project . . . boiler, turbine-generator, transformers, auxiliaries and other apparatus. The benefits of automation may be extended throughout your generating facility. To integrate all stations, Westinghouse offers a completely automatic dispatching system.

THE WESTINGHOUSE NEW POWER CONTROL AND COMMUNICATIONS DEPARTMENT ENGINEERS AND MANUFACTURES:

Systems: supervisory control
voltage regulator
turbine supervisory
automatic dispatching
automatic power plant control
digital telemetering
scanning, monitor and logging (in plant)
scanning, monitor and logging (remote)

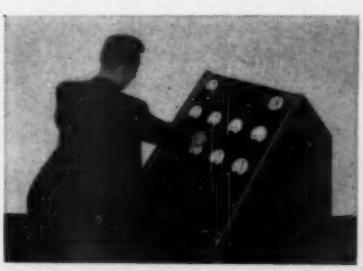
Nuclear: instrumentation and control

Communications: microwave
multiplex
power line carrier

WESTINGHOUSE AUTOMATIC DISPATCHING INCREASES FLEXIBILITY, REDUCES OPERATING COST OF ENTIRE GENERATING SYSTEM. The Westinghouse Automatic Dispatching System provides accurate control of total generation and continuous economic dispatch. Intercompany commitments are maintained while greater economies are realized through accurate computations of transmission losses and incremental loading.

Maximum capability of all machines can be utilized, if necessary, to meet system emergencies without endangering equipment. Massive complexity of today's power systems has forced new levels of accuracy and flexibility. In full consideration of this, Westinghouse offers you an automatic dispatch system that will rapidly repay your investment.

J-60088



YOU CAN BE SURE... IF IT'S Westinghouse

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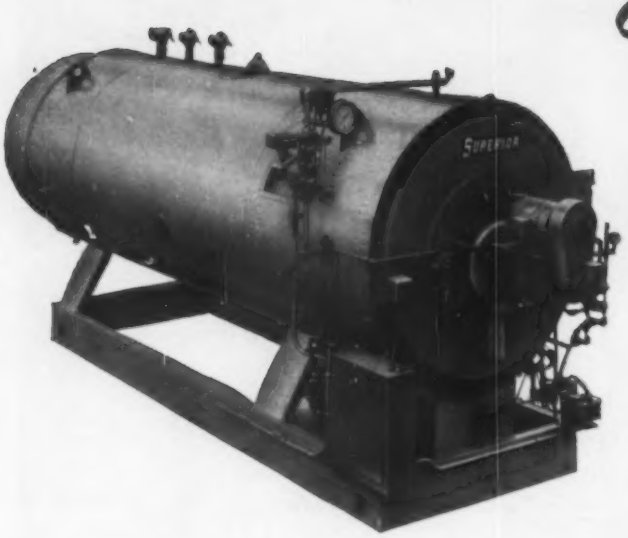

This is the PACKAGED BOILER

that meets ***ALL*** *the "specs"*

BOILER SPECIFICATIONS

Undivided responsibility	✓
5 sq. ft. of heating surface per boiler horsepower	✓
Built-in induced draft	✓
4-pass, down-draft design	✓
Burn oil or gas, or both	✓
Fully automatic operation	✓
Dependable rotary burner	✓
Insulated and jacketed	✓
80% thermal efficiency guaranteed	✓
Factory-fire-tested	✓

Many packaged boilers will meet some of the specifications listed here. Superior Packaged Boilers meet them ALL. Today, more and more packaged boilers are being purchased on the specifications of architects and consulting engineers. Those consulting engineers are demanding that packaged boilers "measure up" to design and performance standards which assure buyers both operating economy and long-lived dependability.

Superior Packaged Boilers . . . built to the highest standards in the industry . . . meet the most exacting "specs", and usually exceed them. That is why Superior Packaged Boilers are so often recommended and so quickly approved by experienced consulting engineers.

In addition to the Type C, illustrated, Superior manufactures both fire-tube and water-tube boilers in a wide range of sizes which makes it the most complete line of fully packaged boilers available. If you will indicate the capacity in which you are interested, we will be happy to assist in the unbiased selection of boiler equipment suited to your specific operations.

Write today for bulletin 12 C.

Specialists in PACKAGED BOILERS . . . exclusively

SUPERIOR COMBUSTION INDUSTRIES, INC.
TIMES TOWER, TIMES SQUARE, NEW YORK 36, N.Y.

SUPERIOR
PACKAGED BOILERS

For more data circle 537 on Post Card

Reader Service Cards provided at right make it easy to get further information on any of this equipment. Just circle the item numbers of the products you want to know more about.

34—12-IN. RECORDER for temperature or pressure

Up to four recording pens can be provided on this 12-in. recorder offered by U. S. Gauge Div. of American Machine & Metals, Inc., for temperature, pressure, or a combination of the two variables. Filled-system thermometer elements are designed to measure temperatures from −300 to 1200 F (fills include mercury, vapor, gas and organic liquid). Pressures from 30-in. of mercury vacuum to 25,000 psi can be recorded (elements include spiral, bellows, C-type Bourdon tube). Recorder features improved case with recessed bottom that permits one type of connection for both wall or panel mounting, and an extra large opening in door for better visibility.

35—DATA LOGGING SYSTEM for new, existing systems

Called APRIL (automatically programmed remote indication logging), this system is designed for applications where accurate centralized data transmitting and logging systems are required. A product of General Electric Co., APRIL can be part of a new supervisory system or added to existing installations of GE equipment. It can be used on its own channel, or on the supervisory channel when required. It can be applied to the petroleum industry, utilities, commercial buildings, industrial power distribution systems. APRIL converts analog-type quantities to a binary code form and transmits information from a remote location by means similar to that used in manufacturer's standard supervisory equipment. When received at a master station, the code is converted to decimal form for visual display or logging using an electric typewriter.

36—REVERSE RELAY gives "fail safe" protection

Pneumatically-controlled industrial process can be given "fail-safe" protection in case of air line failure with the compact Type 783 Reverse Relay, according to The Powers Regulator Co. It is an auxiliary device which gradually reverses the action of pneumatically operated valves, motors and dampers; it converts normally-closed pneumatic equipment to normally-opened operation. When air supply pressure falls to zero, the equipment is designed to revert to normally-closed position and shut down. Only 1¼ in. diam by 2⅝ in. long, this relay is 60 per cent smaller than its predecessor. It mounts on a valve or damper motor, behind control panels, or next to a wall-mounted controlling instrument.

The relay operates on a force-balance principle, balancing pressure of supply and exhaust air against a calibration spring. Fittings are ⅛ in. NPT. Normal air supply pressure is 15 psi; maximum

JANUARY, 1960

NOTE: Card void after April 30, 1960

POWER ENGINEERING

Please have the manufacturers send me without obligation information or bulletins indicated by the numbers circled below.

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Company Address.....

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(If you prefer delivery at home, give home address, too)

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Helpful Bulletins

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Equipment for Automation ...and Reference Booklets

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Advertised Products and Services

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25 psi. Maximum temperature is 160 F, minimum —20 F. More information is provided in Form P-82.

37—MOTOR CONTROLS serve twin pump installations

Type DP Duplex Pump Controls — combination and non-combination — are designed by the Arrow-Hart & Hegeman Electric Co. for control of motors on twin pump installations where two pumps operate individually or in conjunction to provide necessary pumping operation depending on rates required. They provide a disconnect means for every motor, either through fusible or non-fusible switch or thermal magnetic trip circuit breaker placed in series with starter and load. Controls have front-operated mechanism interlocked with cover of enclosure, making it necessary to disconnect circuit before opening door. Control panels feature under-voltage release. Should the power fail on a two-wire control system, the electro-magnet is automatically de-energized since there are no holding circuit interlocks. On resumption of power, electro-magnet is automatically energized without aid of operator.

38—LOW COST CONTROL for coal dust and flyash

The "wet water" dust control system of Deynor Corp. is announced as a simple and inexpensive method for controlling coal dust from unloading point to bunkers by "wetting" and agglomerating dust before it becomes airborne. It consists of a wet water mixer (automatic proportioner) valves, spray nozzles, 1-in. piping and a supply of Veriwet "wet water" cartridges. No pumps, motors or storage tanks are required. The mixer, which operates on the plant water system, replaces these and is said to give effective dust control at less than a cent per ton of coal handled, with mixer, valves and spray nozzles for an average plant costing less than $175. Only other item required — the piping — can be installed by plant personnel. Added moisture is reportedly less than ¾ of 1 per cent.

The system can be manually operated with one control valve, or automatically with solenoid valves, belt trippers etc. The same type of wet water mixer is used for flyash control by connecting it into the water line supplying the spray nozzles in the wetting cylinder. Approximately half the amount of "wet water" as of plain water is required. Data Brochure 66B gives more information.

39—PROGRAM CONTROL also records temperature

Model RCA, a pneumatic temperature program control introduced by The Partlow Corp., functions also as a temperature recorder, and is reported particularly well adapted to locations where steam is a heating medium. Described as a simple and rugged method for program controlling heating applications and providing proportioning valve operation, plus recording, it comes in 10 optional temperature ranges between —30 and 1100 F. Designed to actuate an air-operated throttling valve controlling flow of steam, water or gas or to operate other air-operated devices, Model RCA is engineered for program control using a plastic cam cut to desired

JANUARY, 1960

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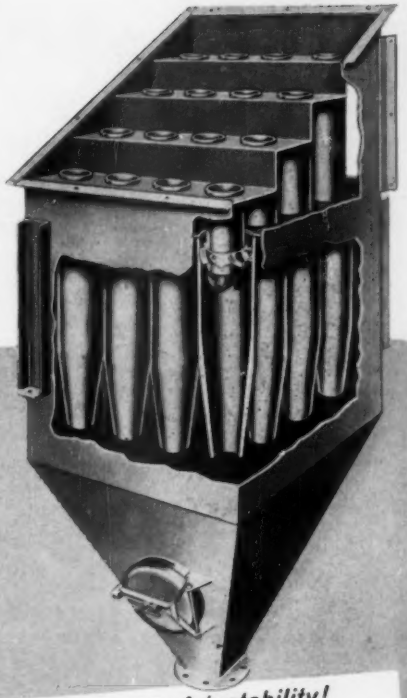
For Modern Fly Ash Control...

Compare

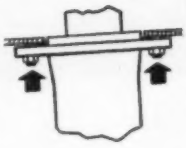
The EXTRA Advantages Built Into MULTICLONE COLLECTORS!



For cyclonic collection of dust or fly ash from all types of gases—hot or cold—no other equipment matches the *multiple* advantages you get in MULTICLONE Collectors. No wonder this small-tube equipment is so widely imitated—but only the genuine Multiclone combines so many important savings as these...

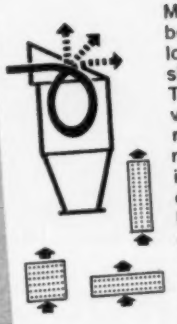
Compare Efficiencies!

Multiclone Collectors pioneered the modern small-tube concept of cyclonic collection. The Multiclone small-diameter tubes combine highest collection efficiency with minimum risk of plugging—and separate not only large, medium and small particles, but also an unusually high percentage of the **extremely small** particles (10 microns and less)!



Compare Maintenance!

Multiclone cast iron tubes and vanes seldom require servicing or replacement. But when unusually abrasive service makes occasional servicing necessary, the tubes (one or more, as desired) can be quickly replaced by simply unbolting the old tube and installing a new one. The cast iron vanes are supported in a tapered seat—are equally easy to service!



Compare Adaptability!

Multiclone Collectors can frequently be placed in otherwise waste-space locations too small—or not properly shaped—for other types of collectors. The shape of the Multiclone can be varied—short and wide, long and narrow, or square—to fit varying space restrictions. Moreover, the unit can be installed with side-inlet, side-outlet—or side-inlet, top-outlet—to fit plant layouts... and only a single inlet and outlet duct is required to service an entire bank of tubes. These multiple advantages add up to important savings in installation, in insulating costs, in space conservation!

Compare Compactness!

In addition to greater space adaptability, Multiclone Collectors also are unusually compact in themselves. For comparable capacity and performance, they require less floor space and less cubic space than do any other cyclonic units. Translate these space savings—plus Multiclone's adaptability to odd-shaped areas—into today's high costs for plant construction and you readily see how important Multiclone compactness really is!

The Above Are Only A Few of the many important advantages you get when you install Multiclone Collectors. Still more are outlined in Multiclone literature that will gladly be sent on request. Write or phone our nearest office for this helpful information!

REMEMBER ...

Western Precipitation is the ONE organization supplying ALL 6 major types of gas cleaning equipment—Precipitator, Cyclonic, Combination, Jet-Cleaned Filter, Hi-Temp Filter and Scrubber. You get a completely unbiased recommendation from Western Precipitation!

Only WP has All 6

1. COTTRELL Electrical Precipitators
2. MULTICLONE Mechanical Collectors
3. CMP Combination Units
4. DUALAIRE Jet-Cleaned Filters
5. THERM-O-FLEX Hi-Temp Filters
6. TURBULAIRE-DOYLE Scrubbers

Also: HOLO-FLITE Processors
HI-TURBIANT Heaters

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M-181

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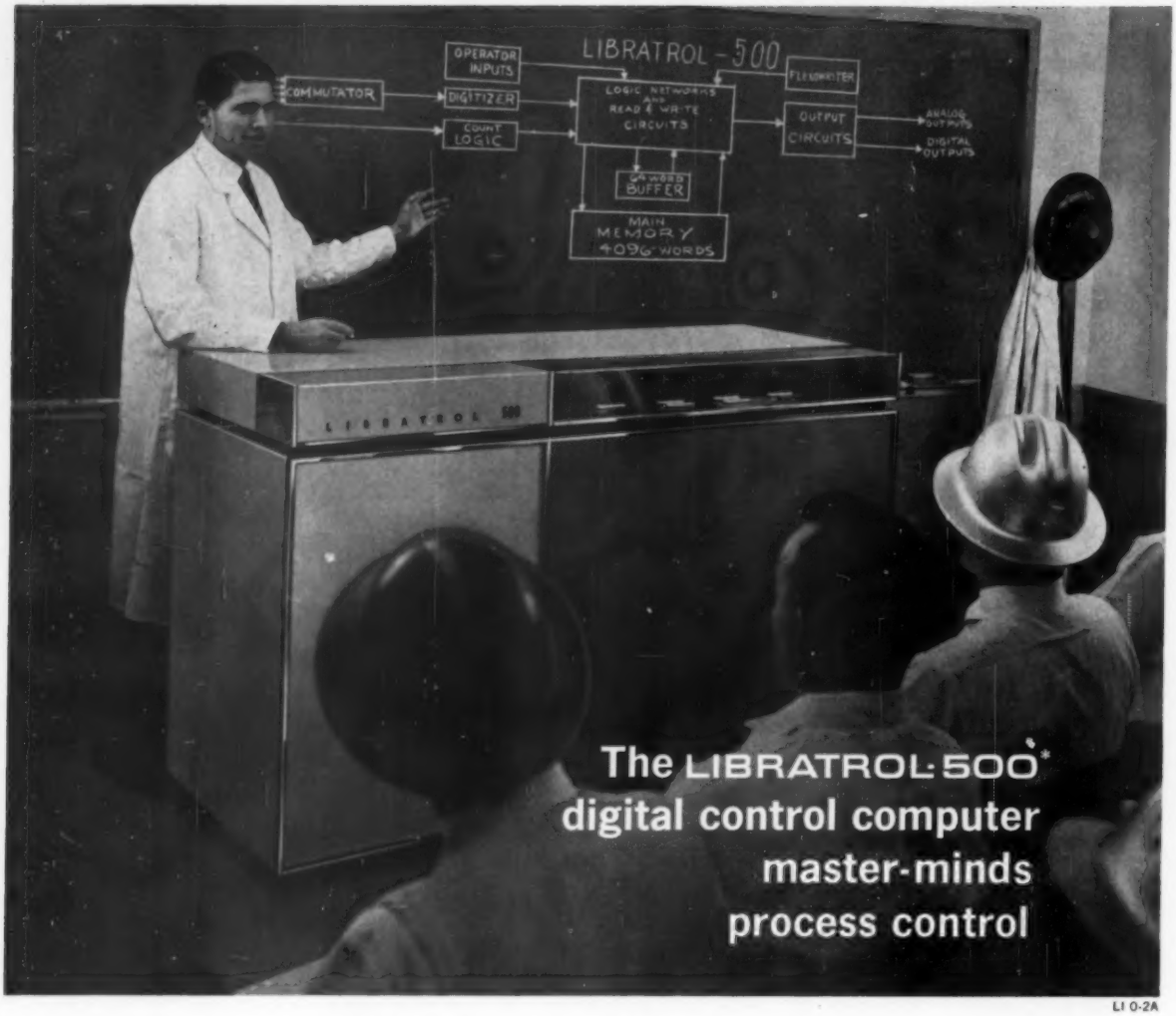

LI 0-2A

The LIBRATROL-500* *by Librascope is more than an on-line control computer.*

■ Even more than a monitoring, computer-directing, and controlling system ... the Libratrol-500 can actually teach industry about its own processes ... can help to establish basic operating criteria.

■ Designed for present computer control techniques, the Libratrol-500 may be used: For the basic operating mode of monitoring and calculating, or the mode of computer-directed control. Or, the system may take full automatic closed loop control of the process.

■ With Libratrol-500, negligible time is used in preparing the data required for making decisions. In most cases it permits control decisions to be made at rates which match the time constants of the process involved.

■ *The Libratrol-500 is a high-speed digital computer-controller designed to handle:*

1. A large number of variables. 120 channels of voltage input data can be digitized and stored in less than 2 seconds, and data from several pulse sources may be introduced simultaneously. Number of inputs may be expanded to 1,000 or more channels by housing input modules in auxiliary cabinets.

2. Temporary information storage. Data can be recorded on the drum, used as needed in calculations, then dispensed with. Through this efficient use of memory space, the machine prints only the results of computations.

3. Rapid computation of control loop functions while handling on-line decisions and control. On one current installation, the Libratrol-500 completes a recurring calculation in one minute ... a problem formerly requiring 45 minutes computation by two engineers.

■ *A wide range of input-output equipment can be accommodated by the Libratrol-500, making the system especially suitable for pipeline automation, petroleum and chemical plants, iron and steel mills, gas and electric utility plants.*

The LIBRATROL-500 offers many unique advantages including:

.....READILY AVAILABLE LIBRARY OF SUBROUTINES.

.....INTERNAL TRUE BINARY REAL TIME REFERENCE.

.....31-BIT WORD LENGTH.

OPERATING INFORMATION

Computer type: General purpose digital.
Memory type: Magnetic drum.
Main memory capacity: 4096 words.
Buffer memory: 64 words.
Add time (Excluding access): 0.25 milliseconds.
Multiply time (Excluding access): 15 milliseconds.
Real time clock: Internal, binary.

■ The Libratrol-500 is typical of Librascope's leadership in creating new computer concepts ... a 22-year leadership based on uncovering needs and meeting them with advanced designs, reliable computing systems.

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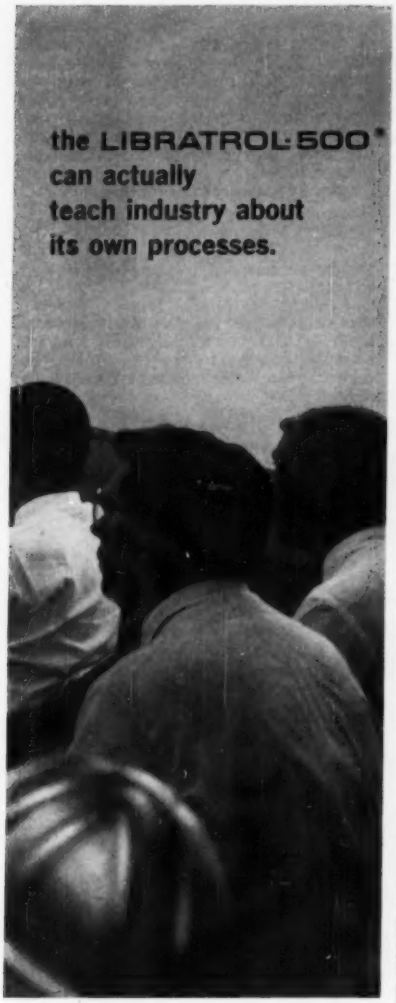


There's a Librascope applications engineer with experience in your industry. Without obligation, he will provide applicable case studies. And on request, he is available to make a feasibility study for computer control of your plant. For complete details, write: Department 310, Librascope, Inc., *808 Western Avenue, Glendale, California.*

LIBRATROL·500*

by **LIBRASCOPE** *a division of* **GENERAL PRECISION, INC.**

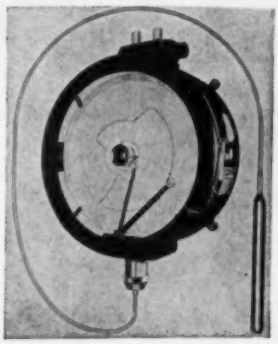
Computers that pace man's expanding mind...

*TRADE MARK

LI 0-2B

temperature range. Several cams can be cut for the same instrument to control different processes.

Also functioning as a temperature



recording instrument, control draws a line on paper charts showing variations in temperature. It is stated that in case of a failure of air supply, valve will shut off, therefore shutting off entire heat supply. Elements of same scale range are interchangeable, permitting field replacement. Bulletin 216 gives full data.

40—ANNUNCIATOR works without moving parts

Statalarm is designed to perform all functions for which relay annunciators are now employed, according to Lundell & Co., featuring long life (100 million operations or more) for flashers and lamp bulbs and it is completely transistorized. All sequences are available in flashing or color. Available for use with any voltage (240 v a-c, 120 v a-c, 48 v a-c or d-c, 24 v a-c or d-c, 12 v a-c or d-c are standard), Statalarm can be used with normally open or closed alarm contacts. Transistors are interchangeable, and built-in emergency power supply is available.

41—MASTER CONTROLLER proportions to load demand

For automatic combustion control systems or comparable industrial applications, Cleveland Controls, Inc. announces an automatic heavy-duty sensing and controlling instrument, responsive to minute changes in pressure or temperature, and transmitting line voltage signals to other system components for control of firing rate, damper positioning valving, etc. With it, firing rate and other process functions are modulated in proportion to load demands. By means of bellows or other sensing ele-

ments, pressure or temperature changes are caused to react on balancing switches. Signals are transmitted to other controllers and actuators for continuous repositioning and regulation to maintain control set point, and signals are transmitted electrically. Models for controlling steam pressure come in ranges of 0 to 30, 20 to 100, and 75 to 300 psi.

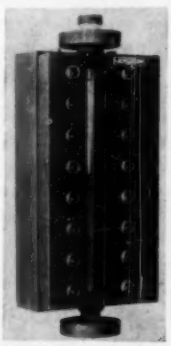
42—FLOW REGULATOR has no moving parts

The Series 300 Micro Adjustable Orifice offered by Stickle Steam Specialties Co. is essentially an adjustable needle valve encased in a sight glass. It is designed to be used instead of steam traps for drain-

age of heating and processing units operating continually at pressures up to 60 psi. The orifice works without moving parts, company says, providing continuous circulation of condensate with virtually no maintenance. Flow of condensate may be minutely regulated by hand key. Sight glass and optional thermometer permit constant visual check. Orifice is for pipe sizes from ½ to 1 in.

43—BOILER GAGE uses light refraction for black-white reading

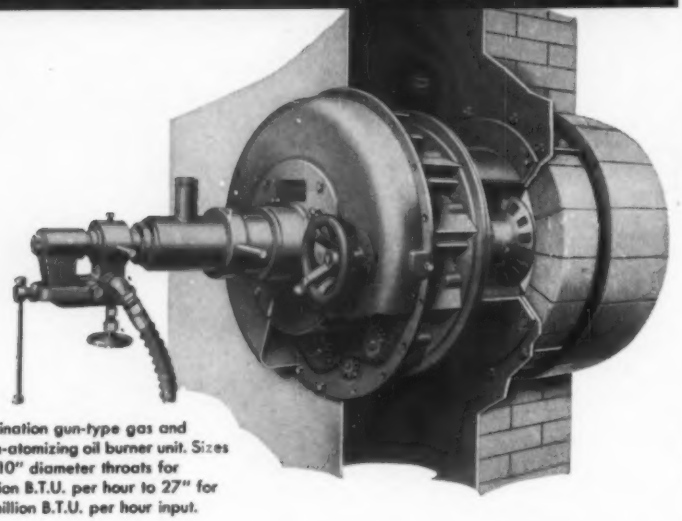
The high pressure Refragage of Jerguson Gage & Valve Co. utilizes the principle of light refraction to provide a sharp black-and-white water level read-



ing with strong contrast similar to that of reflex gages used with lower pressures. It uses a steel plate at both front and back perforated with a line of small, closely spaced holes up and down the 12-in. visible range. A flood light illuminator at the back passes the light rays through an angular passage, and while light passing through the water is refracted and lost to view, light passing through the steam area shines brightly through the front line of holes above

ENCO

TYPE E OIL BURNER UNIT



Combination gun-type gas and steam-atomizing oil burner unit. Sizes from 10" diameter throats for 7 million B.T.U. per hour to 27" for 100 million B.T.U. per hour input.

Saves Money and Troubles IN 5 WAYS

1. Vanes can't stick—Easily adjusted

Air register vanes are easily adjusted by a single hand wheel for either clockwise or counter-clockwise air rotation. The action is without stiffness or sticking. Vane shafts are stainless steel — heat-resistant, corrosion-proof — turn smoothly in carbon graphite bearings at all operating temperatures.

2. Positive Vane Control —no lost motion

Chain-and-sprocket air-vane control, with take-up adjustments, assures easy and precise setting at all times. There are no links to wear and wobble with a flopping action of the vanes when they pass dead center.

3. Adaptable to oil or gas —or both

Changeover from oil to gas or a combination of both can be done easily — with comparatively low cost standardized parts—to get the full advantage of variations in fuel prices.

4. For wide range or standard range burners

Registers accommodate standard range or wide range oil burners — mechanical or steam atomizing — and gun type or ring type gas burners—the one best type or combination for your individual needs.

5. Adaptable to all housing designs

Extra deep burner housing can be used to suit practically any fan and any duct arrangement — with lowest installation cost — and provide proper air distribution for efficient combustion.

Bulletin G59 gladly sent on request

SCS13

THE ENGINEER COMPANY

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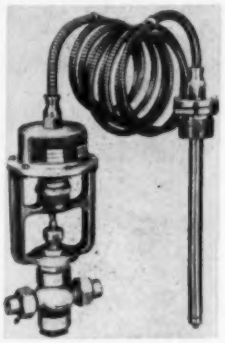
the water level. The effect is similar to that of a reflex gage, giving a clearly marked separation between the black of the water level and the brightly lighted line above. The Refragage is designed for high visibility from a distance and from an angle up to 20 deg. It is also suggested for TV or mirror transmission. It is made of heavily constructed steel for steam pressures to 3000 psi.

44—TEMPERATURE REGULATORS are vapor pressure operated

Cash-Acme Type TC and TCX Series of temperature regulators, introduced by A. W. Cash Valve Mfg. Corp., for use on water heaters, fuel oil preheaters, fuel oil coolers and storage tanks are designed



to control flow of either heating or cooling fluids. Vapor pressure operated, they can be had as direct acting, for heating applications, or reverse acting, for cooling use. The Type TC is available in bronze bodies, ¼- to 2-in. sizes, union connections; in iron or bronze bodies, 2½ to 5 in., 125-lb ASA flanged ends. Temperature ranges are from 25 to 385 F. The Type TCX comes in ¼- to 2-in. sizes, bronze bodies, union connections. It is available in ranges from 50 to 310. Bulletin 7-1 gives details.

45—PROGRAMMER, graph guided, records process performance

The PreKorder, of Research, Inc., is a programming controlling-indicating instrument designed to simultaneously "read" a pencil drawn program chart, control a process accordingly, then superimpose a record of process performance on the same chart. The program appears as a double-line graph pencilled on the circular or strip recording chart. The controller, sensing any deviation of the pen from the middle of the pencilled graph, regulates the process to oppose the deviation.

Two parallel lines defining the process program are connected electrically to the

center tapped transformer winding which serves as a voltage source for an electrostatic field between lines. The pen picks up an error signal proportional to any deviation from its null balance position. This signal is used to effect a readjustment of the process in the proper direction, a technique joining programmer, recorder and process itself into a closed-loop control system.

Programming is done by drawing a double-line graph of desired program on chart paper (Program may be changed by erasing and redrawing.) A record of performance is superimposed on the chart for visual comparison of actual and desired operation. Since the pen senses its position between chart lines without touching them, the chart may be overlayed by clear vellum paper on which the ink record is made, and master chart used repeatedly.

46—PUMP-TANK COMBO for general chemical feeding

This compact and low cost pump-tank combination incorporates Proportioneers Model 1106 Adjust-O-Feeder and is designed by B-I-F Industries, Inc. for minimum space. The 55-gal steel sup-

port drum contains the molded polyethylene tank for the chemicals and is mounted atop a three-legged angle iron frame. The pump, with its strainer, fittings and hoses, is mounted on cross members of frame. Entire unit stands only 53 in. high. Tank, fittings and tubing are of corrosion-resistant materials. Pumping capacity is up to 50 gph for discharge pressures up to 1100 lb.

REFERENCE BOOKLETS on equipment for automation

Supervisory equipment

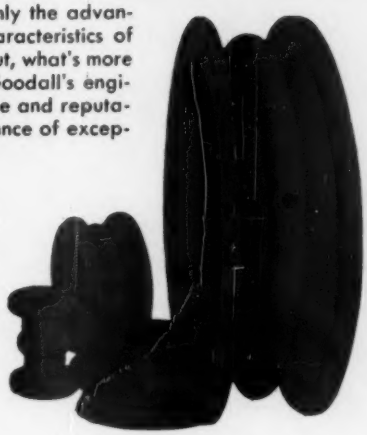
151 **Application of automatically** programmed remote indication logging system for operation in conjunction with its space-code selector supervisory equipment is told in General Electric Co.'s Bulletin GET-2925, 8 pp. Includes information on coding; master and remote station components; adding to existing systems; physical arrangements, control power, operating voltages and channels.

152 **Features of Synchro-Scan for** centralized, economical control of remote operations are covered by Builders-Providence, Inc. in 12-pp Bulletin 240-P24. Synchro-Scan has application in water and sewage plants, chemical plants, power

GOODALL RUBBER COMPANY

Four Good Reasons For Installing GOODALL RUBBER EXPANSION JOINTS

Goodall Expansion Joints have not only the advantages stemming from the natural characteristics of rubber for all types of installations, but, what's more important, they have back of them Goodall's engineering skill, manufacturing experience and reputation for quality that give added assurance of exceptional service under all conditions.



EASIER TO INSTALL...

Goodall Rubber Expansion Joints are quickly, easily installed on new construction or as replacements. They are light in weight to facilitate handling, with short face-to-face dimensions for easier application where space is limited. Retaining rings are quickly aligned and bolted. No gaskets are required.

RESPONSIVE TO MINIMUM PRESSURE...

With Goodall Rubber Expansion Joints only the slightest pressure is required to create movement in any direction. Result—stress on metal pipe or other member is eliminated or, at most, reduced to an absolute minimum.

MANY SIZES...HIGH WORKING PRESSURES...

Goodall Rubber Expansion Joints are available in sizes from ⅜" to 96" I.D., in all required styles and constructions. Working pressures range up to 125 P.S.I. for Pressure Joints, and to 90 P.S.I. for Vacuum-Pressure Joints, depending on size.

LONGER SERVICE LIFE...

Goodall Rubber Expansion Joints last longer in service because of inherent characteristics of the material from which they are made. There is no embrittlement... continuous movement (flexing) actually keeps the rubber joint "alive". There is no corrosion or electrolysis. Resistance to abrasion is exceptionally high. Replacement costs are lower.

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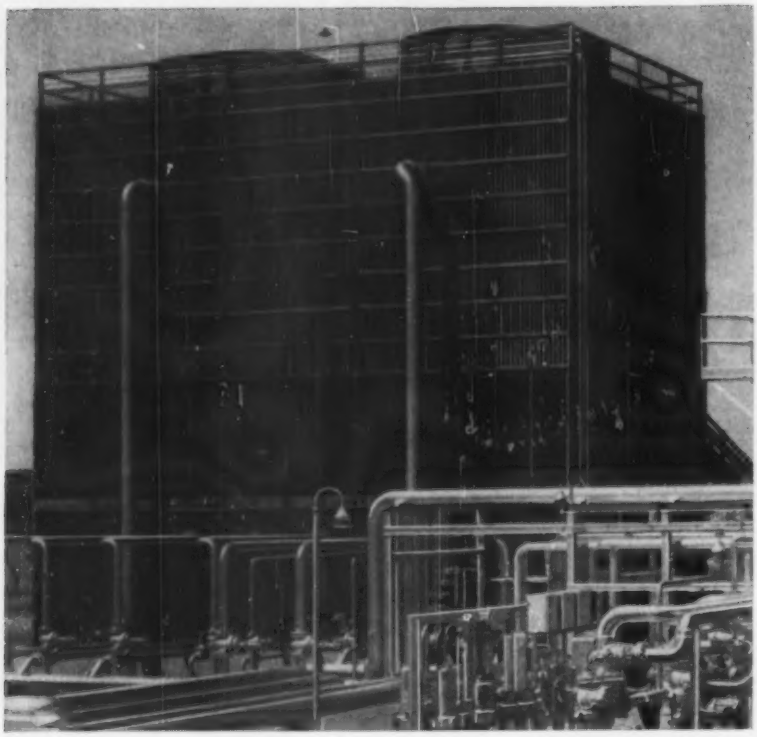
WANT LOWER CORROSION CONTROL COSTS?



Research and experience with water problems in every kind of industry is why the Calgon Company can save you money by lowering corrosion rates and treatment costs. The service starts with a survey of the system, and includes water analysis, both at the source and in use, a review of flow rates, temperatures, equipment types and usage and other pertinent factors. This is followed by complete treatment recommendations and continuing service after treatment is started. Here is why Calgon methods can save you money and maintenance:

LOWER CHEMICAL COSTS: In most systems, treatment is substantially lower in cost. This is because of more effective treatment, which means that smaller amounts of chemicals can be used.

LOWER WATER COSTS: With more effective treatment, it is frequently possible to maintain higher solid concentrations in cooling water. This means less makeup water, and consequent savings in overall water costs.

BETTER RESULTS: In one typical plant, water treatment in use resulted in a corrosion rate of 4 mils per year. When Calgon methods took over, corrosion rates were reduced to 1 mil per year, troublesome deposits were also eliminated, and chemical costs came down at the same time.

A letter or phone call will put Calgon Engineers to work on your particular problem.

CALGON COMPANY
HAGAN BUILDING, PITTSBURGH 30, PA.

DIVISION OF HAGAN CHEMICALS & CONTROLS, INC.

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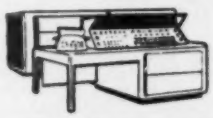
substations, industrial process operations, others. What it is, how it works, how it affords simplified control and can be expanded are among subjects treated.



Computers and data processing equipment

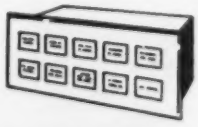
153 **Details on PowrMag solid** state analog computer control systems are presented in Bulletin MSP-163, Hagan Chemicals & Controls, Inc. Describes entire systems and provides diagrams showing interchangeable circuits possible for various control functions. Numerous applications to industrial process control are suggested, with emphasis on centralized plant or multi-plant control, expansion of existing control facilities.

154 **Data processing equipment of** Leeds & Northrup Co. now in use throughout the country is described in 48-pp Preliminary Technical Publication N-07(1). Installations covered include digital data processing and analog and digital computing systems. The illustrated bulletin explains types of inputs, input switching, output devices and modes of operation for applications in electric power, petrochemical, other fields. Leeds & Northrup Co.

155 **Technical data on all functions** of the Kybernetes Series 2000 Data System are presented in this 12-pp bulletin by Hagan Chemicals & Controls, Inc. Covers inputs, d-c amplification, analog-to-digital conversion, linearization, programming, integration, computer control and others. Specifications for all components and functions of the system, together with a typical system block diagram, are included.

156 **Act I, an electronic algebraic** compiler and translator, is described in 18-pp Manual S-520 of Royal McBee Corp. Explains the "source" program language — a series of algebraic and logical statements. Stresses simplicity of use, faster programming and thus faster computer solutions to engineering and control problems.

157 **Magnetic tape for digital and** analog instrument recording is shown in Bulletin 1619 of Consolidated Electrodynamics Corp. Information includes performance qualities of the tape, production techniques and specifications.



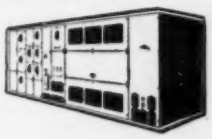
Annunciators

158 **Well illustrated with photos,** charts and diagrams, 52-pp Catalog 100C of the Panalarm Div., Panellit, Inc., presents information on annunciator systems designed to give immediate notification of off-normal conditions in continuous process and automatic operations. Discusses function and applications of annunciators and types of equipment, with mechanical and engineering data included.

159 **Comprehensive information** on operation and application of annuncia-

tor system to provide continuous and automatic surveillance of pipeline, chemical and food processing, power generation and distribution is given by The Scam Instrument Corp. in 36-pp Catalog 659. Types of annunciator sequences are illustrated and described, annunciator diagrams included, and engineering data provided.

160 **Fail-Safe Annunciator is illustrated** and described in Bulletin 108 of Panalarm Div., Panellit, Inc. It is designed to differentiate between its own component failure and an alarm in the system being protected. Advantages, operation details and features are covered.



Instrumentation designed for specific functions

161 **Details on Accuray on-stream** instrumentation for process industries manufactured by Industrial Nucleonics Corp. are given in 12-pp Bulletin PI-959. Covers continuous level measurement system, level detector-controller, continuous density measurement system, container fill control systems and others. Specifications, applications and operating characteristics provided.

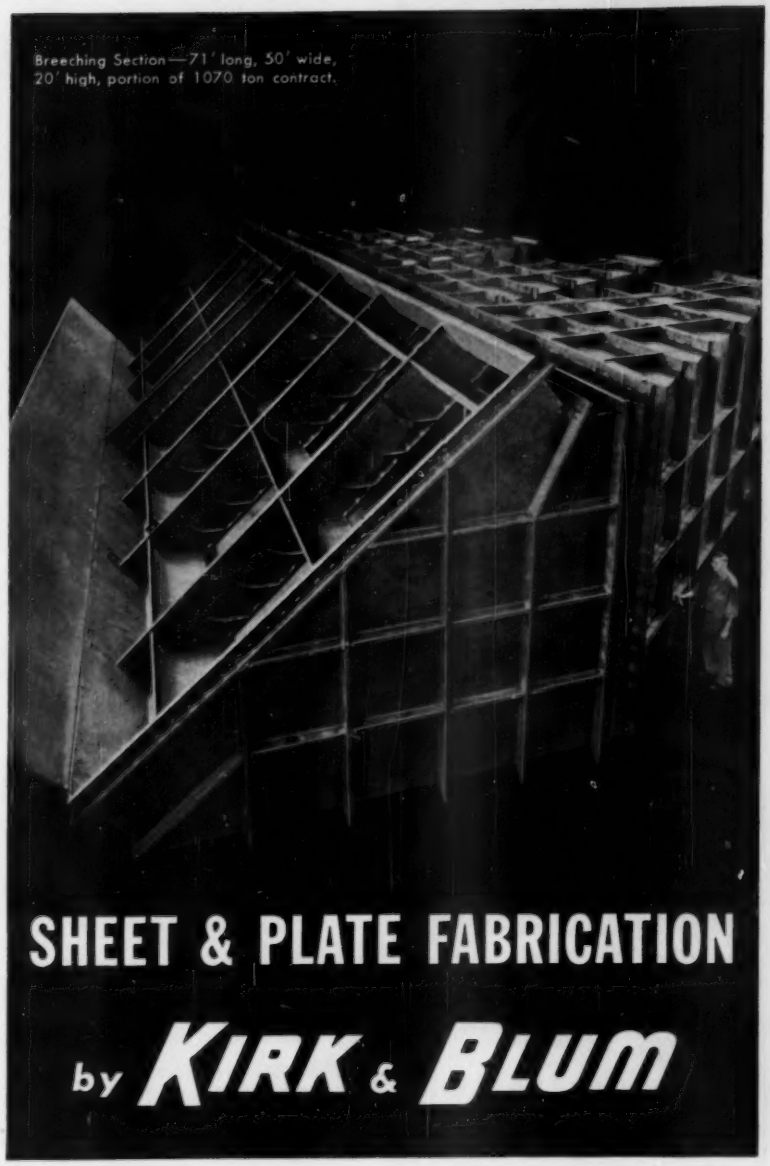
162 **C.-A.-P. System instruments** for automatic operation and control of filter plants, for operation on 3 to 15 psi output pressures, are described by Infilco, Inc. in 16-pp Bulletin 1100C. They include integrated components for opening, closing and modulating valves, regulating chemical feed rates, and indicating and recording flow rates, levels and pressures.

163 **Control assemblies for water** conditioning and ion exchange systems are described by Permutit Co. in 12-pp Bulletin 4543. Covers panels and cubicles containing centralized instrumentation for automatically controlling, recording, signaling and monitoring system operations.

164 **Provided in 30-pp Booklet** D97-2 of Minneapolis-Honeywell Regulator Co. is a compilation of article reprints on instrumentation for treatment of water and sewage. What instruments are used, how they are used and their functions in controlling automatically the many variables in treatment process are among topics covered.

165 **Guidebook to automation** through modernization for the metal rolling and processing industry is offered in Catalog GED-3893 of General Electric Co. Describes step-by-step approach to automation in detail, covering five basic areas of operation common to all metal-rolling and processing industries — reversing hot mills, hot-strip mills, cold mills, processing lines, and specialized processes. General Electric Co.

166 **Pre-wired, panel control systems** for automatic oil, gas or dual-fuel burners in industrial and commercial boiler installations are described by Iron Fireman Mfg. Co. in Folder 5803-A. Includes dimensions, illustrations, selection chart for identification of panel assemblies.



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Heavy assemblies, up to ½" thickness are produced, pre-assembled and loaded for shipping in a 50' x 480' bay with overhead handling capacity up to 25 tons.

Send prints for prompt quotation or write for your copy of new K&B Sheet and Plate Fabrication Catalog.

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ACCURATE!

The TAYLOR WATER ANALYZER

Has Guaranteed Color Standards That Give DEPENDABLE Data

For fast, yet completely accurate tests of pH, hydrazine, silica, ammonia, total iron, nitrate and other elements in water, use a Taylor Water Analyzer. One basic, low cost unit is adaptable for use with 18 guaranteed color standard slides. Allows you to make many determinations required in plant operations. Tests are made in only minutes. No fragile glass standards to handle. Complete instructions included with every kit. Also available—Midget Iron Testers, Total Hardness Sets, Sulfite Comparators, Nitrate Comparators. Sulfite and Nitrate color standard slides available separately for use with phosphate or pH base.

For Fast, Accurate, pH, PHOSPHATE TESTS

TAYLOR COMPARATORS

Compact, portable Taylor Comparators let you make on-the-spot pH, chlorine and phosphate tests in minutes. No experience necessary. Just fill the center tube with treated sample and move color standard slide across until sample matches one of the standards. Values are then read directly from the slide.

Be sure to use only Taylor reagents and accessories with Taylor Comparators to assure accurate results. Sealed-in-plastic color standards are guaranteed against fading.

SEE YOUR DEALER for Taylor sets or immediate replacement of supplies. Write direct for FREE HANDBOOK, "Modern pH and Chlorine Control". Gives theory and application of pH control. Illustrates and describes full line.

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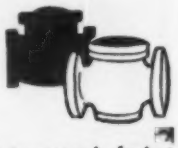
167 **Boiler control system serving** Deepwater Station at Atlantic City is described in detail in 12-pp Bulletin 1057, Copes Vulcan Div., Blaw-Knox Co. This system is designed to maintain a constant pressure in the main process steam header by holding steam output from the boiler equal to steam demand. Illustrations include photos of components, schematic diagram of system.

Valves



169 **In addition to cross indexing** company's own line of valves with those of other manufacturers, The Ohio Injector Co.'s Valve Buyer's Guide, 22 pp, contains a list of frequently used abbreviations, a valve trim chart, other data. A breakdown by valve material and pressure class, and classification by type, disc design, seating arrangement, stem operation, bonnet and end connection serve as an additional guide to selection.

170 **Information on silent check** valves designed to combat surge and water hammer problems is given by Combination Pump & Valve Co. in this 20-pp bulletin. Photos of typical installations are included, as well as engineering data and flow charts.

171 **Air, water and oil cylinders** and valve-cylinder combinations for automation applications offered by Airmatic Valve, Inc., are described in 24-pp Bulletin 91017. Features and advantages are detailed, and specifications and dimensional data and diagram included.

172 **Eight butterfly valve designs** for 9000 applications are presented in tabular form in Bulletin 50-1 of Continental Equipment Co., Div., Fisher Governor Co. Sizes of valves shown range from 1 to 108 in., pressure drops up to 1200 psi, temperatures to 2000 F. Manual and power actuators are also shown.

173 **Reported ideal for throttling** service, the Monoflange Mark II of Henry Pratt Co. is introduced in Bulletin 10-G, a 16-pp working guide on this rubber seat butterfly valve. In sizes to 20 in., this valve mounts between flanges and is designed to provide leak tight closure at 150 psi, maximum temperature 200 F. Catalog gives full specifications, certified dimension drawings, water and gas flow data, weights and freight rates, prices. Also describes manual and automatic operators available.

174 **Features of an advanced design** pressure sealing gate valve are highlighted in this color-illustrated bulletin of W-K-M Div., ACF Industries, Inc. Stresses improved sealing afforded by floating seats, automatic relief of excessive body pressures, quick changing of seats on the line, other advantages. Specifications included.

175 **Solenoid valves available "off** the shelf" from Automatic Switch Co. are presented in 16-pp Stock List and Selection Guide 506. Contains engineering information, simple selection data and illustrations and flow diagrams of two-, three- and four-way types, manual reset valves, and special purpose valves and strainers. Price and shipping information also provided.

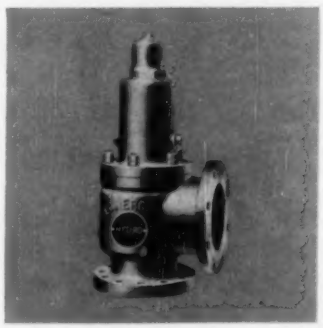
THE LONERGAN LINE

HOW TO SAVE WEAR AND TEAR ON MEN AND VALVES

by A. J. Schmidt, Chief Engineer

Power plant users of relief valves in liquid service are undoubtedly all too familiar with chattering. Valves hammer away, annoying plant personnel and running up maintenance bills.

Even with this undesirable operation, these



valves have been acceptable for application where the valves are seldom, if ever, called upon to relieve. For use under critical applications, such as pump by-pass, where the valve is normally open, or where opening is a common occurrence, it has been necessary to use expensive diaphragm or piston operated valves to eliminate objectionable chattering.

A new series of valves, called Lonergan Hydro-Valves have been under test in dozens of leading plants for the past three years. As a result, Lonergan can provide power plant operators with a valve that is guaranteed not to hammer, chatter or drum on any application, by-pass or emergency relief. At the same time, full-rated liquid flow is maintained. The chatter free operation is provided by a patented, unique design of throat, seat and baffle construction. Use of the Hydro-Valve helps to: save human nerves; prevent loss of plant fuel or product; reduce maintenance on valves and piping; and eliminate interference with delicate control systems. Hydro-Valves are available in all regular body and trim materials in sizes ranging from 1 to 8 inches.

Full details and descriptions are available in our new Hydro-Valve bulletin. Why not write for your copy today?

Alvin J. Schmidt

Lonergan

J. E. LONERGAN CO., 207 RACE STREET
PHILADELPHIA 6, PA. SINCE 1872

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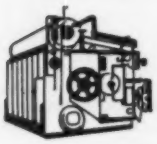
176 **In Bulletin W-2-A, 8 pp,** Golden Anderson Valve Specialty Co. tells of a surge relief valve designed to protect water lines against overpressure in the system. With this valve, pressure itself supplies power to operate valve automatically. Engineering information, drawings and suggested specifications are provided.

177 **Characteristics and advantages** of ductile iron regulators and control valves are detailed in OPW-Jordan's Bulletin J-DI. These regulators are said to combine strength of steel with corrosion resistance of cast iron. Composition, properties, specifications, comparison tables on steel, cast iron and red brass are furnished.

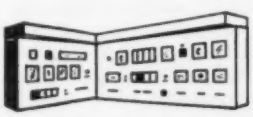


Steam generation

178 **Typical applications of the** Coal Pak, an automatic boiler, are presented in Specifications GS-3, about 36 pp, by Bituminous Coal Institute. Covers use as low pressure heating plant, low-temperature hot water plant, and high pressure process plant. Illustrations include plan views, wiring diagrams for field connections, ash conveyor details.

179 **Packaged automatic boilers,** Powermaster Model 3, are presented in 12-pp Bulletin 1260, Orr & Sembower, Inc. Covers gas, oil and combination gas-oil models, a hot water boiler and steam atomizing principle for use with No. 6 oil. Ratings and dimensions of all sizes are given, as well as details of burners.

180 **Features and advantages of a** fully automatic unit steam generator for light oil, heavy gas, and combination gas-oil applications are described in Bulletin 3000 of Preferred Utilities Mfg. Corp. Tables of steel specifications of pressure vessel, engineering and dimensional data are included.



And other equipment

181 **Electric recorders for a variety** of applications are grouped by accuracy class for convenient selection in General Electric Co.'s, Bulletin GEA-6933, 12 pp. Complete specifications are provided, along with dimensions and chart speeds, applications, features and data on accessories.

182 **Helpful data on automatic** removal of air from refrigeration systems is given by Armstrong Machine Works in 12-pp Bulletin 700. This purging guide answers such questions as why purging is necessary, how non-condensable gases affect efficiency, methods of purging, where to make purge connections, and how to use refrigerated purger.

183 **Installation through start-up** service for automation and instrumentation systems offered by Panellit Service

DEKORON ARMORED INSTRUMENT HARNESS

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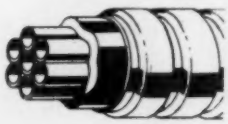
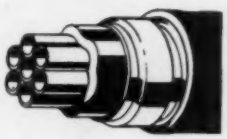
CONSTRUCTIONS

TYPE VA



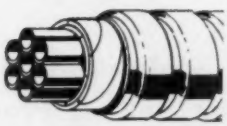
For Impact and Corrosion Resistance. Core tubes with vinyl sheath covered with Moore-Loc modified-square-lock construction armor with cord packing.

TYPE VAV



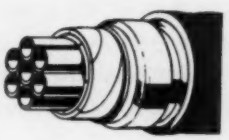
For Impact and Maximum Corrosion Resistance. Same construction as Type VA (*above*) but with outer vinyl sheath. 24-gauge galvanized steel armor gives maximum pull-apart and impact resistance.

TYPE A



For Impact Resistance in Dry Locations. Core tubes are wrapped in vinyl-impregnated insulating tape. Tape insulates and cushions core tubes inside metal armor.

TYPE AV



For Corrosion and Impact Resistance. Same construction as Type A (*above*) but with outer vinyl sheath. All four constructions available with metal or plastic core tubes.

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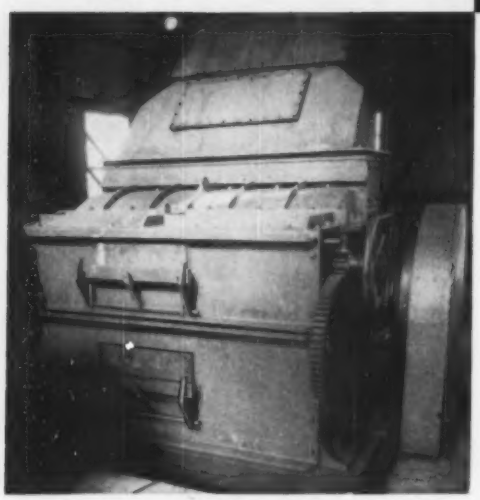

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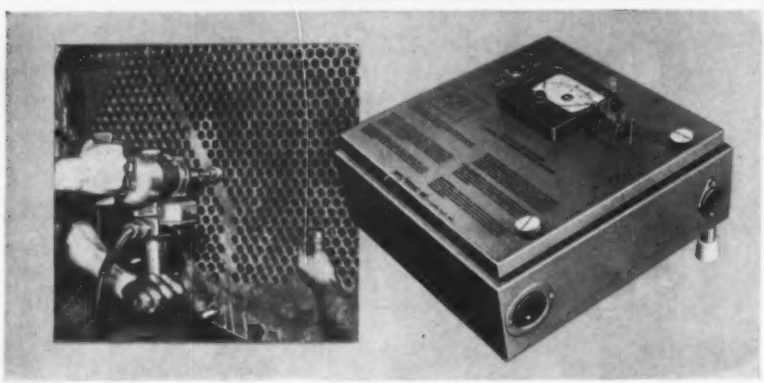

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Corp. are described in 16-pp Bulletin 107 Services include a contract organization furnishing installation drawings, installation of panels, field instruments, field interconnections, commissioning, operator orientation and supplementary instrumentation personnel where needed.

184 **Reference Bulletin 430B, 8 pp,** of Peabody Engineering Corp., describes features of company's automatic fuel burner. Design and construction details are illustrated.

185 **Pneumatic force-balance** transmitters for measurement of level over range spans of 1 in. water to 2000 in. water are covered in Bailey Meter Co.'s Product Specification P31-1. Simplified diagram shows operation of reset booster relay.

186 **Selection data for thermocouple** wells and assemblies are presented in 18-pp Catalog G102-1, Minneapolis-Honeywell Regulator Co. Information covers well designs and dimensions, pressure and temperature ratings, corrosion data, and ordering and pricing.

187 **Information on pneumatic** spreader coal stokers which automatically meter, dry, preheat, convey and fire all sizes of coal and all grades from lignite to best bituminous is given in 12-pp Booklet 2530 of Iron Fireman Mfg. Co. Cutaway views, installation photos and diagrams illustrate text.

NEW ENGINEERING BOOKS

The Diesel Engine: Its Theory, Basic Design and Economics, by L. V. Armstrong and J. B. Hartman; 360 pages, 5 by 8 in., cloth. Published by The Macmillan Co, 60 Fifth Ave, New York 11, N. Y. Price $8.75.

Reflecting the authors' extensive experience in the diesel engine field, this book is a comprehensive and logical treatment of the subject. A discussion of petroleum and refining methods is followed by a consideration of diesel fuel combustion. Authors then examine the effect of forces released by combustion upon the moving parts of the engine and on the static or restraining parts of the engine. After a treatment of "parasitic engine parts," there is a final section on economics, including power application.

An outstanding characteristic of the book is the introduction, at strategic points, of a basic design problem, pointing up the practical value of the theory with which it is associated.

★ ★ ★

Principles of Direct-Current Machines, by Alexander S. Langsdorf; 363 pages, 6 by 9 in., cloth cover. Published by McGraw-Hill Book Co, 327 W. 41st St, New York 36, N. Y. Price $8.50.

This text presents a compact analysis of the operating characteristics of direct-current generators and motors, based on the necessary relations between the magnetic and elec-

trical circuits which constitute their structural design.

Basic principles of electromagnetism which are needed in developing the characteristics of rotating machines are presented in the opening chapter, together with a full discussion of the systems of units in which magnetic and electrical quantities are expressed. The remainder of the book is concerned with the properties and construction of the machines themselves. Design considerations which determine the dimensions of machines have been touched on to the extent necessary to answer questions that occur naturally to inquiring students.

In this Sixth Edition, the first five chapters of the previous edition have been eliminated, except for the parts dealing with electromagnetism, which are now included in the first chapter and Appendix A. Chapter on armature windings is completely rewritten and simplified. This chapter now includes a description of a new type of unipolar generator which appears here in textbook form for the first time.

★ ★ ★

Electric Motors and Generators, by Emery, Harrabin, Lee, Nixon and Rapson; 384 pages, 5 by 8 in., cloth cover. Published by Philosophical Library, Inc, 15 E. 40th Street, New York 16, N. Y. Price $12.

A product of British authors, purpose of this book is to provide understanding for those outside the professional ranks of electrical engineering of the basic and fundamental principles of generators and electric motors.

The book avoids complex electrical theory and mathematics as far as possible. It describes all types of d-c and a-c motors and generators: their design, construction, installation, operation and maintenance.

While emphasis throughout is on the practical approach, there is an appendix explaining the fundamentals of electrical theory for the benefit of those whose knowledge of the subject is slight or needs brushing up.

★ ★ ★

Advanced Mechanics of Fluids, Hunter Rouse, editor; 444 pages, 6 by 9 in., cloth cover. Published by John Wiley & Sons, 440 Fourth Ave, New York 16, N. Y. Price $9.75.

This book is a sequel to Rouse's **Elementary Mechanics of Fluids,** through which the reader became familiar with the underlying philosophy of the subject and the use of its principles in the solution of both new and routine engineering problems.

In this new work, such introductory knowledge is at once presumed; hence, full attention is given to broadening the reader's analytical ability and understanding. The goal is the development of research methods whereby the frontiers of the science itself can be further enlarged. To this end, the theoretical approach is given primary emphasis, yet the reader is not permitted to forget that experience must ever remain the control of scientific progress.

While the book as a whole has obviously been planned for use in formal classes, it also

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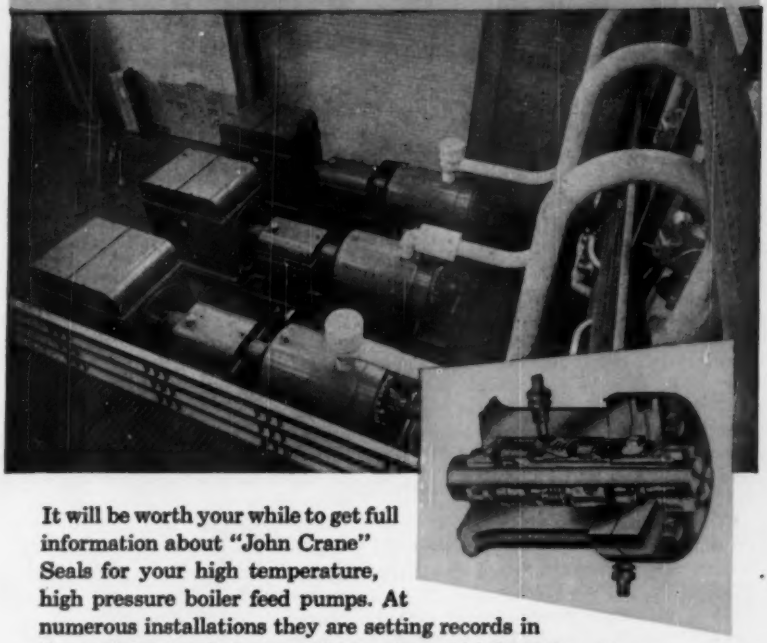

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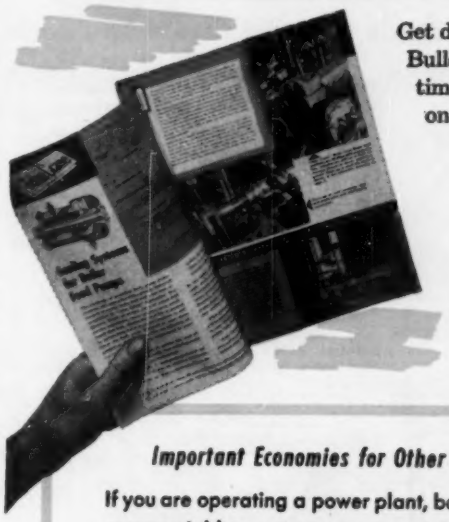

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has a definite role in self-instruction, and the combination of text, examples, problems and answers will permit a well-qualified reader to make satisfactory progress without other guidance.

★ ★ ★

Economic Operation of Power Systems by Leon K. Kirchmayer; 260 pages, 6 by 9½ in. Published by John Wiley & Sons, 440 Fourth Ave, New York 16, N. Y. Price $12.

Book discusses "electronic brain" methods used by electric utilities to promote economy in production. It emphasizes theoretical developments and computer use in dealing with and solving system problems. It shows how matrix methods are employed to derive transmission loss formulas which, in turn, are the basis for computational procedures applied to computers. Proper use of analog and digital computers to obtain transmission loss formulas and generation schedules is also described. Additional features of the book include mathematical models, analytical methods, and computer applications to prediction and improvement of performance of systems, and many new theories and tools of power system operation.

★ ★ ★

Thermodynamics, by Gordon J. Van Wylen; 567 pages, 6 by 9½ in. Published by John Wiley & Sons, 440 Fourth Ave, New York 16, N. Y. Price $7.95.

Book was written, according to the author who is Professor of Mechanical Engineering at University of Michigan, to fulfill three objectives: to provide an approach to the subject directed primarily at engineering students; to provide a rigorous treatment of fundamentals; and to convey a distinctly engineering perspective. Thus, the author concentrates on giving the student an appreciation and understanding of both the physical and mathematical aspects of thermodynamics.

In addition, the appendix contains a complete set of steam tables and thermodynamic properties tables of various gases.

★ ★ ★

Uplift in Gravity Dams, by Serge Leliavsky; 267 pages, 6 by 9 in., cloth. Published by Frederick Ungar Publishing Co, 131 E. 23rd St, New York 10, N. Y. Price, $9.50.

Of the three types of forces which comprise the main causes of stress commonly considered in designing a gravity dam, the third — pressure of water infiltrating through the material of the dam, or "lift" — is still the subject of controversy. Dr. Leliavsky has been dealing with the cycle of problems involved in lift since 1942, and has now assembled the substance of his work in book form. He is the author of *Introduction to Fluvial Hydraulics*, and has had a long career, both as a practical engineer and as a professor, in the hydroelectric fields in Russia and Egypt. This new book covers calculation methods, experiments and design theories.

Heating Ventilating Air Conditioning Guide 1959; 768 pages, 8½ by 11 in. Published by American Society of Heating, Refrigerating and Air-Conditioning Engineers, 62 Worth St, New York 13, N. Y. Price $12.

This 37th edition of the guide contains larger illustrations, working charts and tables, including 286 new or revised diagrams and charts. Technical Data Section follows general format of previous editions and is divided into 12 general sections:

Fundamentals; Environment, Comfort, and Physiological Principles; Heating and Cooling Loads; Room Heating and Cooling Methods and Equipment; Air Systems and Equipment; Steam and Water Systems and Equipment; Heat Generating Methods and Equipment; Refrigeration, Spray Apparatus and Sorbents; Controls, Instruments, and Motors; Specific Applications; Industrial Systems; General.

Subjects for five new chapters are: High Temperature Water Systems, The Heat Pump, Evaporative Air Cooling, Humidification, and Snow Melting.

★ ★ ★

Modern Air Conditioning, Heating, and Ventilating, by Willis H. Carrier, Realto E. Cherne, Walter A. Grant, and William H. Roberts; 592 pages, 7 by 10½ in. Published by Pitman Publishing Corp, 2 W. 45th St, New York 36, N. Y. Price $12.

This third edition of this work incorporates a complete revision of all chapters where progress in the art of heating, ventilat-

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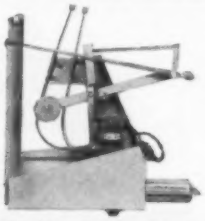

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The easiest—and quickest—way to order bulletins and catalogs described in this magazine is to use the postage-free Reader Service Cards on pages 101–102.

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★ ★ ★

Power Plant Theory and Design, by Philip J. Potter; 710 pages, 6 by 9 in., 16 chapters. Published by Ronald Press, 15 E. 26th Street, New York 10, N. Y. Price of the book is $10.50.

The author, Head Professor of Mechanical Engineering at Alabama Polytechnic Institute, has revised and updated the original volume, published originally in 1949 and widely used as a college text. As in the first edition, principal attention is given to large central station power design because such stations include all the problems of method and equipment that would be involved in the design of industrial plants and smaller power plants.

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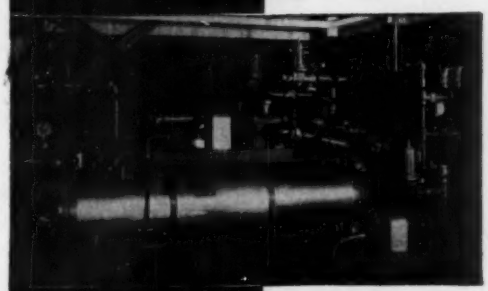

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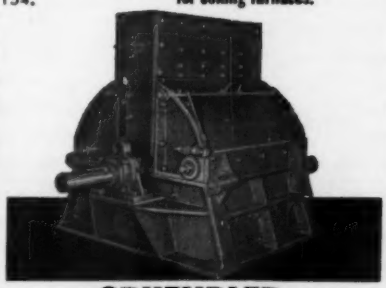

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world's largest family of valves

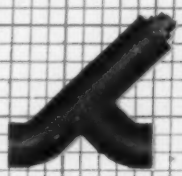

Fig. 1365A—Small Steel Pressure Seal "Y" Check Valve for 1500 pounds W.S.P. Socket weld ends. Sizes ½" to 2". Also available for 2500 pounds in sizes ½" to 3".

Fig. 11303—Steel Pressure Seal Gate Valve for 1500 pounds W.S.P. The higher the pressure within the valve the tighter the seal at body-bonnet joint. 600, 900, 2500 pound valves can be furnished.

Fig. 3061A WE—Newly designed Steel Swing Check Valve for 300 pounds W.S.P. Has straight flow through area when disc is in wide open position.

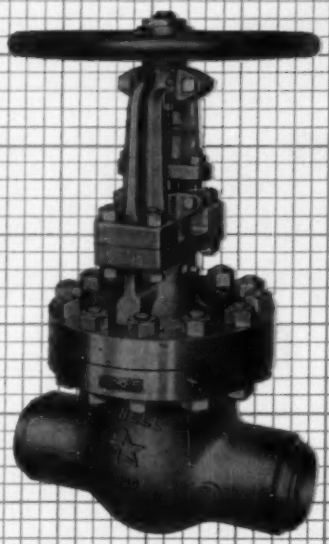

Fig. 9003 WE—Steel Gate Valve for 900 pounds W.S.P. Outside screw rising stem and yoke. Solid wedge disc. Steel valves are available for pressures from 150 through 2500 pounds.

Fig. 512—Small Bronze Gate Valve for 150 pounds W.S.P. Inside screw non-rising stem. Solid wedge disc. Can also be supplied with flanged ends.

Fig. 1444—Large Iron Body Bronze Mounted Gate Valve for 125 pounds W.S.P. Outside screw rising stem and yoke, double wedge disc. Also available with solid wedge disc.

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Ideal for Hospitals, Hotels, Apartments, and Industries where noise is objectionable.

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This self-contained unit comprises a powerful motor, rotatably mounted on a stand, a required length of heavy duty flexible shaft, a 20 ft. cable, and a selection of heads, brushes, drills, and scrapers to meet any cleaning need. The motor swivels and rotates so that tubes on top, bottom, and sides can be cleaned without moving the unit. A few of the many types of heads available are shown below.

Bulletin 107 gives full details of this quiet, efficient, convenient tube cleaner. Send for it now.

Rotojet Electric Tube Cleaner with swing-frame head.

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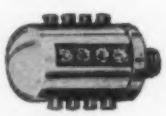

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in boilers, steam and return lines . . .

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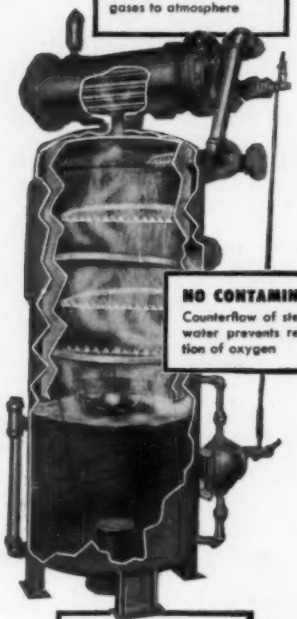
SAVES STEAM
Vent Condenser releases only air and contaminated gases to atmosphere



NO CONTAMINATION
Counterflow of steam and water prevents reabsorption of oxygen

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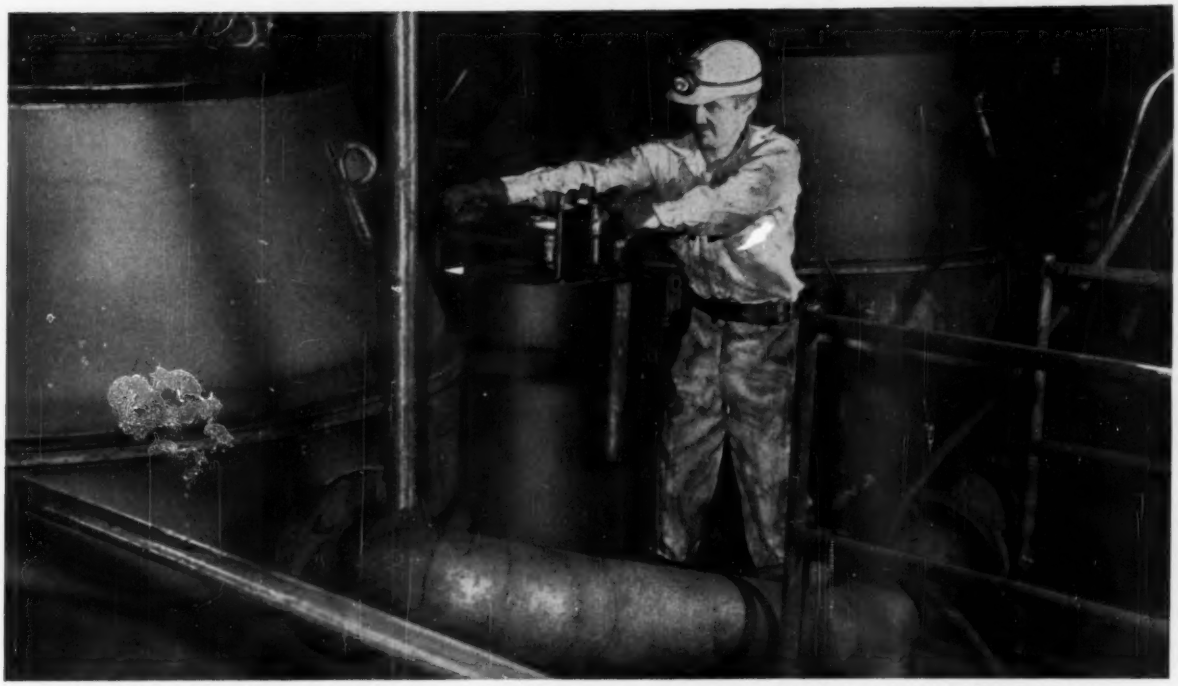

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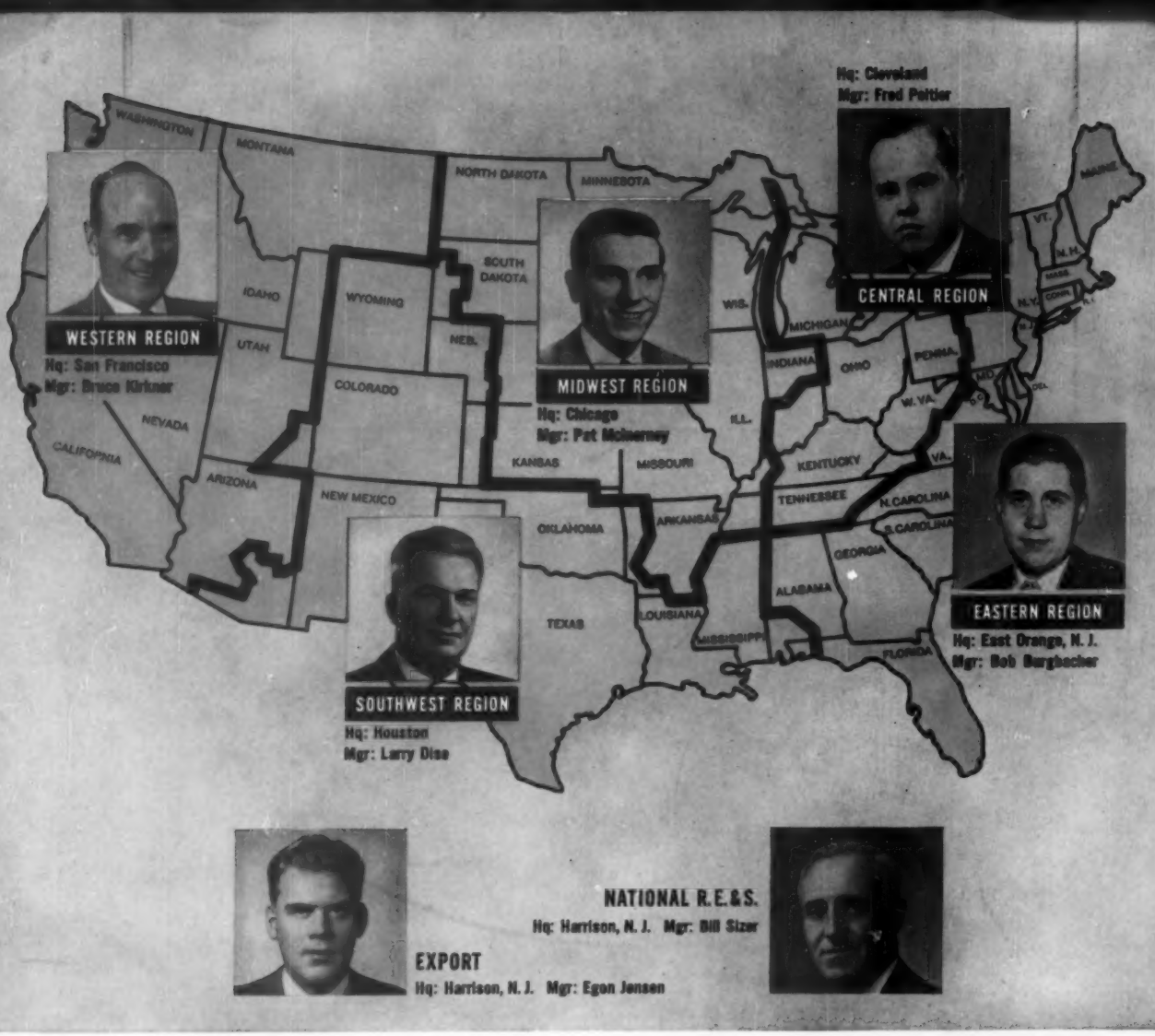

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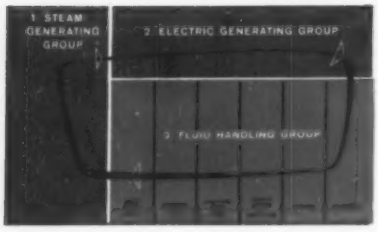

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